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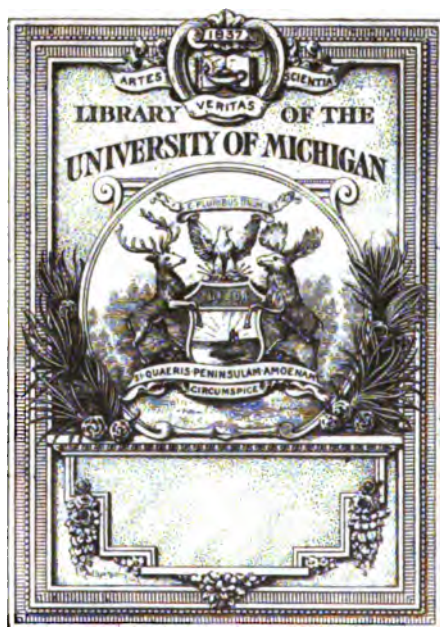
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1912-13

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,

WILLIAM A. TAYLOR, *Chief of Bureau.*

BULLETINS
OF THE
BUREAU OF PLANT INDUSTRY.

NOS. 269 TO 281.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1918.

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, WILLIAM A. TAYLOR.

Assistant Chief of Bureau, L. C. CORBETT.

Editor, J. E. ROCKWELL.

Chief Clerk, JAMES E. JONES.

TITLES OF BULLETINS NOS. 269 TO 281 OF THE BUREAU OF PLANT INDUSTRY.

Issued from December 31, 1912, to May 6, 1913.¹

BULLETIN No. 269.—Experiments in Wheat Breeding: Experimental Error in the Nursery and Variation in Nitrogen and Yield. By E. G. Montgomery. Issued April 24, 1913.

BULLETIN No. 270.—Contributions to the Study of Maize Deterioration. Biochemical and Toxicological Investigations of *Penicillium Puberulum* and *Penicillium Stoloniferum*. By Carl L. Alsberg and Otis F. Black. Issued March 11, 1913.

BULLETIN No. 271.—Some Effects of Refrigeration on Sulphured and Unsulphured Hops. By W. W. Stockberger and Frank Rabak. Issued December 31, 1912.

BULLETIN No. 272.—Heredity of a Maize Variation. By G. N. Collins. Issued January 21, 1913.

BULLETIN No. 273.—The Muscadine Grapes. By George C. Husmann and Charles Dearing. Issued May 5, 1913.

BULLETIN No. 274.—Wild Wheat in Palestine. By O. F. Cook. Issued April 3, 1913.

BULLETIN No. 275.—Apples and Peaches in the Ozark Region. By H. P. Gould and W. F. Fletcher. Issued May 6, 1913.

BULLETIN No. 276.—The Utilization of Waste Raisin Seeds. By Frank Rabak. Issued March 22, 1913.

BULLETIN No. 277.—A Biochemical Study of the Curly-Top of Sugar Beets. By Herbert H. Bunzel. Issued March 19, 1913.

BULLETIN No. 278.—Floral Abnormalities in Maize. By James H. Kempton. Issued April 2, 1913.

BULLETIN No. 279.—The Effects of Artificial Shading on Plant Growth in Louisiana. By H. L. Shantz. Issued April 16, 1913.

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¹ Bulletins Nos. 252 to 254, 256, 258, 263, 264, and 266 to 268 were also issued during this period.
1635—13



Issued April 24, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 269.

B. T. GALLOWAY, *Chief of Bureau.*

EXPERIMENTS IN WHEAT BREEDING:

EXPERIMENTAL ERROR IN THE NURSERY AND
VARIATION IN NITROGEN AND YIELD.

BY

E. G. MONTGOMERY,

*Experimental Agronomist of the Nebraska Agricultural Experiment Station
and Collaborator of the Office of Cereal Investigations,
Bureau of Plant Industry.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
WASHINGTON, D. C., *October 16, 1912.*

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 269 of the series of this Bureau the accompanying paper entitled "Experiments in Wheat Breeding: Experimental Error in the Nursery and Variation in Nitrogen and Yield," by Prof. E. G. Montgomery. This paper contains the results of special experiments in wheat breeding conducted by the Nebraska Agricultural Experiment Station in cooperation with the Office of Cereal Investigations of this Bureau, during the years 1905 to 1910, inclusive. In part, the work is a continuation of that recorded in Bureau of Plant Industry Bulletin No. 78, by Dr. T. L. Lyon, under whose direction the experiments were conducted from 1902 to 1906, inclusive. From 1907 to 1910, inclusive, the work was under the charge of Prof. Montgomery, experimental agronomist of the Nebraska experiment station, who has since become professor of farm crops in the College of Agriculture at Cornell University.

The paper is concerned chiefly with the nature and extent of experimental error in the wheat nursery in connection with breeding experiments in the inheritance of nitrogen content and yield in wheat plants. The standardization of agronomic experiments has been receiving much attention in recent years and is regarded as of fundamental importance in agronomic research. The results contained in this paper are presented as a contribution to this subject as well as to the improvement of wheat.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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EXPERIMENTS IN WHEAT BREEDING: EXPERIMENTAL ERROR IN THE NURSERY AND VARIATION IN NITROGEN AND YIELD.

I.—EXPERIMENTAL ERROR IN THE NURSERY AND VARIATION IN NITROGEN CONTENT.

INTRODUCTION.

The investigation of the variation of plants of winter wheat in relative nitrogen content when grown under field or nursery conditions was begun by Dr. T. L. Lyon, formerly agronomist of the Nebraska Agricultural Experiment Station, in collaboration with the Bureau of Plant Industry of the United States Department of Agriculture. His results were published as a bulletin of that bureau.¹ Since 1907 the investigation has been continued by the writer and his assistants.²

One of the striking features of the data obtained by Dr. Lyon was the variation in nitrogen content of the kernels from different plants of wheat grown under apparently similar conditions. For example, 800 spikes of Turkey wheat were selected and half of each spike analyzed for proteid nitrogen, the lowest having only 1.12 per cent while the highest contained 4.95 per cent.

In 1903, 288 plants which were the progeny from 119 of the spikes analyzing above 3 per cent proteid nitrogen in 1902 were analyzed and found to vary from 1.20 per cent to 5.85 per cent in nitrogen content. In most of the families only a single plant was selected for analysis, but in the remainder two to six plants were selected. Even where all the plants were grown from a single parent the variation was quite as great.

¹ Lyon, T. L. Improving the Quality of Wheat. Bulletin 78, Bureau of Plant Industry. 1905.

² The writer wishes to acknowledge with thanks the assistance of a number of men who have contributed to the production of these data. Dr. T. L. Lyon, now of Cornell University, planted the first wheat nursery in 1902 and conducted the work until 1906, being assisted by Prof. Alvin Keyser, now of the Colorado Agricultural Experiment Station. They left an excellent set of records, from which data previous to 1906 have been prepared (Table II). Mr. L. L. Zook, now of the Bureau of Plant Industry, assisted with the work in 1907 and 1908, as did Mr. Erwin Hopt in 1908 and 1909. Prof. T. A. Kiesselbach had charge of the records during the seasons of 1909 and 1910 and has prepared much of the tabular matter for publication. The chemical analysis has been under the direction of Dr. F. J. Alway, who devised a rapid method especially for this work.

Dr. Lyon noted this variation, as follows:

For instance, the plants numbered 21205 to 21212, all of which come from the same parent, vary from 2.16 to 5.23 per cent in proteid nitrogen content, while plants 69805 and 69806 vary from 5.82 to 1.66 per cent in this constituent.¹

In addition to the 119 "highs" preserved in 1903, progeny were analyzed also from 20 "mediums" and "lows." When these data were summarized it seemed that there had been some tendency to transmit the character, as shown in Table I.

TABLE I. *Results of a study of transmission of nitrogen content in wheat kernels in 1902 and 1903.*²

Range in percentage of proteid nitrogen.	1902		1903	
	Number of analyses averaged.	Proteid nitrogen in kernels.	Number of analyses averaged.	Proteid nitrogen in kernels.
1 to 3.....	20	Per cent. 1.85	70	Per cent. 2.59
3 and over.....	119	3.39	288	2.92

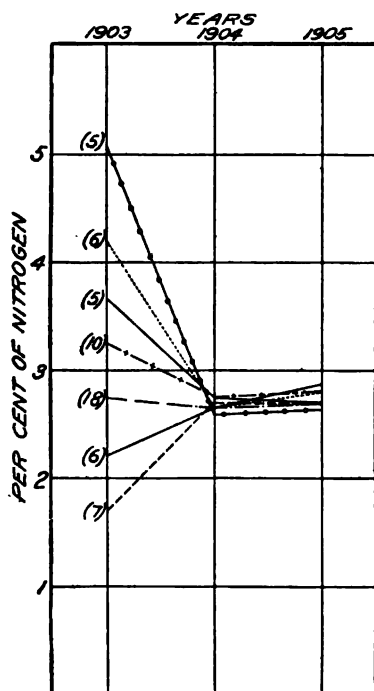


FIG. 1.—Diagram showing the transmission of nitrogen content in 57 wheat plants of 1903 to progeny in 1904 and 1905. The vertical lines represent successive years. The horizontal lines represent the percentage of nitrogen found, and the figures in parentheses show the number of plants in each group analyzed for nitrogen content in 1903.

Summaries of the results obtained in 1904 and 1905 show very little tendency to transmit this character.

In 1906, after four years of selection of extremely high fluctuates, and later, after two more years of selection, by taking a composite sample of all the progeny of a plant it was found that no gain had been made in the nitrogen content of the crop.

In Table II is a summary of data obtained in the years 1903 to 1905 from 57 of the original plants. Figure 1 is a graphic presentation of the same data, in which the horizontal lines represent the percentage of nitrogen, the vertical lines represent successive years, and the figures in parentheses show the numbers of plants in each of the seven groups analyzed for nitrogen content in 1903.

¹ Lyon, T. L. Op. cit., p. 99.

² Lyon, T. L. Op. cit., table 26, p. 98.

TABLE II.—*Nitrogen content of 57 wheat plants in 1903 and of their progeny in 1904 and 1905, arranged in groups according to the percentage of nitrogen.*

Record of 57 plants harvested in 1903.					Record of progeny plants in 1904.					Record of progeny plants in 1905.				
Number of analyses.	Kernels per plant.		Nitrogen in kernels.		Number of analyses.	Kernels per plant.		Nitrogen in kernels.		Number of analyses.	Kernels per plant.		Nitrogen in kernels.	
	Average number.	Weight.	Per cent.	Weight.		Average number.	Weight.	Per cent.	Weight.		Average number.	Weight.	Per cent.	Weight.
		Gms.		Gms.			Gms.		Gms.			Gms.		Gms.
7.....	555	10.82	1.68	0.1709	35.....	641	9.12	2.69	0.2491	112....	1,052	17.71	2.68	0.4806
6.....	654	14.66	2.20	.3040	35.....	790	12.63	2.63	.3262	99.....	1,040	19.13	2.84	.5207
18.....	601	11.26	2.74	.3068	90.....	745	11.42	2.64	.2845	285....	1,165	21.44	2.69	.5716
10.....	338	5.87	3.27	.1919	53.....	664	10.59	2.74	.2947	180....	1,067	19.49	2.82	.5486
5.....	306	6.44	3.68	.2431	23.....	723	10.56	2.74	.2875	51.....	1,093	23.16	2.71	.6154
6.....	366	6.62	4.25	.2837	30.....	779	11.54	2.65	.3137	98.....	1,245	22.02	2.80	.6153
5.....	274	5.68	5.13	.2773	25.....	716	10.56	2.59	.2710	81.....	1,183	20.12	2.64	.5317

It is difficult to explain why such great variations exist when there seems to be little or no tendency to transmit them. It seems apparent that the variations must be due to differences in environment. Since the ordinary factors of environment, as sunlight, warmth, moisture, and apparent fertility of the soil, are constant for all plants under our nursery conditions, we must conclude that there are factors profoundly influencing the growth of plants beyond the ordinary range of observation.

Figure 2 shows the general appearance of the centgener nursery, each centgener containing 100 plants 6 inches apart each way. Figure 3 shows a single centgener just after growth has started in the spring, about 40 per cent of the plants having winterkilled. The great variation in the size of the remaining plants is probably due to the effect of environment and is not hereditary. This environmental variation is usually noted even in centgeneres where most plants have survived and is often interpreted as indicating real hereditary differences.

A number of interesting problems are suggested. Why should one plant, growing under practically the same environment as another, collect from the soil two or three times as much nitrogen? Or why should two plants yielding different quantities of grain collect the same quantities of nitrogen? Table III illustrates these variations.

TABLE III.—Data from six wheat plants, showing irregular variation in yield and in nitrogen content of grain.

Plant No.	Kernels.		Nitrogen in kernels.		Plant No.	Kernels.		Nitrogen in kernels.	
	Number.	Weight.	Per cent.	Total weight.		Number.	Weight.	Per cent.	Total weight.
		<i>Grams.</i>		<i>Grams.</i>			<i>Grams.</i>		<i>Grams.</i>
21107.....	1,058	22.879	2.45	0.5805	23905.....	776	18.507	3.57	0.6607
21108.....	1,030	16.679	2.59	.4324	23907.....	1,167	23.018	2.86	.6593
21109.....	927	16.026	1.74	.2789	24005.....	1,495	30.064	2.19	.6584

The three plants, Nos. 21107 to 21109, are from the same mother growing in a single centgener, probably less than 2 feet apart, yet the actual grams of nitrogen gathered differ more than 100 per



FIG. 2.—Centgener nursery, Nebraska Agricultural Experiment Station. Each centgener contains 100 plants.

cent. This difference is not inherited, as these plants rarely transmit this quality. It therefore seems hard to explain on a difference in the root development or in the functioning parts of the plant. As plants growing only 6 inches apart commonly exhibit such differences, it can not be ascribed to a difference in soil solution. Difference in vigor of growth is not a satisfactory explanation, as plants Nos. 23905, 23907, and 24005 illustrate. These three plants under uniform conditions yielded different quantities of grain, yet the heaviest yielder produced no more nitrogen than the lowest. Such differences are not only common among plants from the same centgener, but quite marked variations are also noted between centgeners from the same mother plant.

Some of the results obtained from the study of this problem are shown in figures 4 and 5. Figure 4 is a plat of a single centgener (1907), with the plants 6 inches apart each way, making the entire area 5 feet square. All plants in this centgener are from the same parent. Each square represents a plant. Where no figures occur the plant was missing. The upper number shows the percentage of nitrogen, the central number represents the kernels borne by the plant, and the lower number the weight in grams of the good kernels. Each plant was harvested separately, the kernels counted and weighed, and the percentage of nitrogen determined. Two wave lines indicate plants analyzing above 3 per cent nitrogen and one wave line those



FIG. 3.—Wheat centgener just after growth has started in spring, showing about 40 per cent of the plants winterkilled. Note the great variation in size of the remaining plants.

analyzing between 2.8 and 3 per cent. A tendency to group is noted. Those containing between 2.56 and 2.80 per cent are not marked. One straight line indicates plants with between 2.55 and 2.40 per cent of nitrogen; two straight lines, less than 2.40 per cent.

Figure 5 shows a section of the wheat nursery in 1907. The small squares represent centgeners 5 feet square and the heavy lines outline family groups; that is, all the plants and centgeners within a heavy line came from the same original plant. The percentage of nitrogen was obtained by taking a composite sample from all plants on the centgener. Variation is quite marked, although there is some tendency for certain families to run high or low; as, for example, family 339.

An illustration of the irregularities in number and weight of kernels, in percentage of nitrogen, and in total yield of nitrogen per plant is afforded in Table IV, pedigree records of two families. The wide variations were supposed at first to represent natural fluctuations which would be in some degree transmitted, but the selection of these high fluctuations has had no apparent effect in modifying the

<u>2.32</u> 682 17.8	<u>2.32</u> 429 13.0	<u>2.46</u> 450 14.0	<u>2.24</u> 385 12.8	<u>2.21</u> 247 6.80	<u>2.32</u> 299 8.86	<u>2.52</u> 501 13.4	<u>2.52</u> 361 10.0	X	<u>2.55</u> 445 15.7
<u>3.04</u> 225 5.8	2.79 500 15.5	<u>2.52</u> 481 13.4	<u>2.41</u> 284 8.1	2.60 507 13.8	2.60 401 11.1	2.68 347 9.8	2.63 549 15.0	<u>2.52</u> 411 11.8	2.72 513 12.5
<u>3.86</u> 535 14.3	2.60 633 16.7	2.56 657 18.6	2.56 562 14.5	<u>2.53</u> 409 9.8	<u>2.50</u> 417 10.1	2.56 227 5.3	2.75 543 14.3	<u>2.82</u> 298 7.0	2.56 681 17.5
<u>3.06</u> 325 4.9	2.73 767 18.7	X	<u>2.50</u> 225 5.0	<u>2.29</u> 410 11.0	2.56 284 8.0	2.63 390 9.4	2.66 378 9.3	<u>2.82</u> 466 10.4	<u>3.09</u> 423 8.9
2.62 957 25.2	2.59 715 18.2	X	<u>2.49</u> 464 10.8	<u>2.45</u> 322 8.9	2.75 406 9.7	2.69 392 9.5	<u>3.16</u> 218 3.8	<u>3.10</u> 352 7.6	<u>3.58</u> 144 2.8
X	X	<u>2.89</u> 535 11.1	2.65 141 3.1	<u>2.42</u> 363 8.5	<u>2.90</u> 251 5.2	<u>2.96</u> 228 4.8	3.09 319 6.6	3.20 430 6.0	<u>3.38</u> 421 9.5
2.75 719 22.2	<u>2.46</u> 382 10.3	<u>2.55</u> 421 11.9	<u>2.41</u> 155 4.1	2.71 457 5.3	X	<u>2.86</u> 425 8.9	2.60 379 7.4	<u>3.10</u> 295 6.3	X
2.59 290 7.1	2.60 600 18.8	<u>2.28</u> 425 10.4	<u>2.28</u> 329 9.0	2.66 470 11.1	2.76 239 5.5	2.77 362 4.8	<u>3.07</u> 194 3.3	<u>3.27</u> 510 10.8	<u>2.90</u> 368 6.5
X	<u>2.15</u> 292 7.4	<u>2.39</u> 325 8.7	2.63 460 17.4	<u>2.52</u> 661 16.8	X	<u>2.80</u> 641 14.4	<u>2.96</u> 466 11.1	<u>2.89</u> 488 11.8	X
X	2.66 832 22.9	<u>2.18</u> 258 7.6	<u>2.48</u> 716 19.6	2.58 576 14.4	2.60 510 12.1	<u>2.80</u> 540 14.6	<u>2.82</u> 339 7.0	2.58 313 8.1	<u>3.11</u> 395 7.5

Fig. 4.—Wheat centgener of 100 plants, showing variations in yield of grain and of nitrogen in 1907. Upper figures, percentage of nitrogen content; middle figures, number of kernels produced; lower figures, weight of good kernels in grams. The various underscorings of the upper figures indicate five groups having successively higher nitrogen content as follows: (1) Figures underscored with two straight lines lie between 2.15 and 2.40 per cent; (2) those underscored with one straight line lie between 2.41 and 2.55 per cent; (3) those not underscored lie between 2.56 and 2.59 per cent; (4) those underscored with one wave line lie between 2.80 and 3 per cent; (5) those underscored with two wave lines lie above 3 per cent.

nitrogen content of plants in a family, as there always seemed to be a mean content for each family, to which the types returned.

As examples of variation, note that No. 35809 in family 42 has a low yield of nitrogen, yet the yield of nitrogen found in its progeny is practically equal to that of other members of the family. In family 48 (Table IV) note that in 1903 the three plants selected analyzed 3.82, 4.43, and 5.48 per cent of nitrogen, respectively,

while the family as a whole contained 3.53 per cent. The progeny of these plants returned to normal in percentage and total yield of nitrogen, except No. 21909, in which the yield of grain was above the average. Just why these wide fluctuations occur when every precaution is taken to grow the plants under uniform conditions is not very apparent.

In 1908 a more thorough investigation of this point was made. Twenty-nine plants from the 1907 crop were all selected from a single centgener, and therefore all came from a single plant in 1906. From each of these 29 plants a centgener was planted, and also a row 14 feet long. The 29 centgeners were planted side by side, also the 29 rows. At harvest time all the plants in each of the 10 adjacent

2.35	2.64	2.65	2.93	3.04	2.89	2.73	2.56	2.59	2.89	2.77	2.62	2.55	2.77	2.71	2.55	2.89	2.48	2.77
313	314	314	328	328	381	381	385	385	405	405	417	417	522	522	556	556	3	3
2.44	2.60	2.72	3.00	2.45	2.72	2.75	2.71	2.72	2.50	2.83	2.43	2.58	2.93	2.99	2.52	2.52	2.68	3.02
313	314	314	328	328	381	391	385	385	391	405	417	417	522	522	556	556	3	3
2.54	2.62	2.69	2.93	2.92	2.57	2.82	2.53	2.62	2.53	3.00	2.53	2.49	2.93	3.11	2.59	2.68	2.50	2.36
313	314	314	317	338	381	385	385	385	391	405	417	417	522	522	556	556	3	3
2.58	2.60	2.63	2.73	3.17	2.89	2.53	2.53	2.76	2.49	2.89	2.59	2.63	2.66	2.95	2.55	2.66	2.55	3.03
313	314	316	317	339	381	385	385	385	391	405	417	417	522	522	556	556	632	3
2.34	2.69	2.84	2.60	3.16	2.80	3.02	2.66	2.93	3.06	2.87	2.75	2.71	2.89	2.92	2.39	2.63	2.62	2.96
313	314	316	317	339	381	385	385	385	391	407	417	417	522	555	556	556	632	3
2.72	2.76	2.87	2.87	3.17	2.89	2.49	2.80	2.71	2.48	2.89	2.60	2.68	2.69	2.68	2.92	2.69	2.68	2.95
313	314	316	317	339	381	385	385	390	391	407	417	417	522	555	556	556	632	3
2.46	2.35	2.93	2.90	3.09	2.79	2.60	2.89	2.73	2.77	2.82	3.00	2.77	3.00	2.83	2.88	2.83	2.54	2.83
313	314	316	317	339	381	385	385	390	391	407	408	417	522	555	556	556	632	3
2.62	2.80	2.89	2.73	3.13	2.43	2.63	2.56	2.76	2.68	2.92	2.84	2.71	3.03	2.97	2.59	2.79	2.62	2.89
313	314	316	317	332	379	385	385	390	391	408	408	425	522	555	555	556	556	3
2.35	2.59	2.76	2.63	2.58	2.87	2.73	2.68	2.60	2.68	2.69	2.89	2.66	2.72	3.02	2.73	2.76	2.69	2.68
313	314	316	317	377	379	385	385	390	391	408	408	425	425	555	555	556	556	3
2.87	2.44	2.86	2.63	2.46	2.82	2.73	2.63	2.86	2.66	2.59	2.83	2.52	2.63	2.77	2.73	2.68	2.71	2.66
314	314	316	317	377	379	385	385	390	391	408	408	425	425	555	555	556	556	3
2.87	2.80	3.00	2.71	2.79	2.84	2.66	2.49	2.65	2.68	2.79	2.87	2.90	2.62	3.16	2.84	2.72	1.76	2.68
314	314	316	317	377	379	385	385	390	391	408	408	425	425	555	555	556	556	3
2.77	2.58	2.96	2.72	2.63	3.20	2.73	2.73	2.72	2.77	2.84	3.02	2.64	2.65	2.79	2.90	2.62	2.11	2.73
314	314	316	317	377	377	385	385	390	390	408	408	425	425	555	556	556	556	3

FIG. 5.—Diagram of a portion of the wheat nursery in 1907, showing variations in nitrogen content in cent-geners and families. Each square represents a single centgener, and each area within heavy lines shows the centgeners belonging to a single family. The upper figures represent the percentage of nitrogen; the lower figures are the family numbers.

centgeners were harvested in order and analyzed. The 10 duplicate rows were grown in a manner similar to field conditions; that is, sown at the rate of 5 pecks to the acre and the rows 8 inches apart. The plan was to see whether the same sort of variation would be found among plants under field conditions. To secure a uniform sample from the rows, 7 plants were harvested from each foot of row, 98 plants being harvested and analyzed from each row. In the centgeners the results were similar to those obtained in 1907. The plants in the rows, being planted close together, yielded only about one-tenth as much grain per plant, but the variation in yield and in percentage of nitrogen per plant was even greater than in the centgeners.

Year	21905	21906	21907	21908	21909	21910	21911	21912	21913	Average
1905	701	14,311	2,64	3,778	38205	761	10,7984	2,52	2721	10905
1906	158	10,453	2,43	3,540	38206	502	7,4332	2,26	1719	10906
1907	173	2,893	3,35	3,840	38207	597	8,3134	2,30	1912	10907
		3,5574	3,83	1,339	38208	803	12,0218	2,32	2758	10908
					38209	1,145	16,8802	2,38	3971	10909
					Average	761.6	11,0806	2,36	2622	Average
					38305	979	13,3663	2,57	3435	
					38306	1,000	14,2411	2,54	3617	
					38307	739	11,2404	2,85	3203	
					Average	739	11,2404	2,85	3203	Average
					38308	1,175	16,6016	2,50	4173	
					38309	973	13,5882	2,46	3345	
					Average	973.6	13,8275	2,48	3555	Average
					38605	704	11,0436	2,34	2594	
					38606	956	14,0310	2,61	3662	
					38607	652	8,2336	2,77	2281	
					38608	1,130	16,8943	2,30	3870	
					38609	563	7,2238	2,64	1907	
					Average	801.0	11,4713	2,53	2861	Average
					388.2	8,3406	3,53			
					Average	388.2	8,3406	3,53		Average

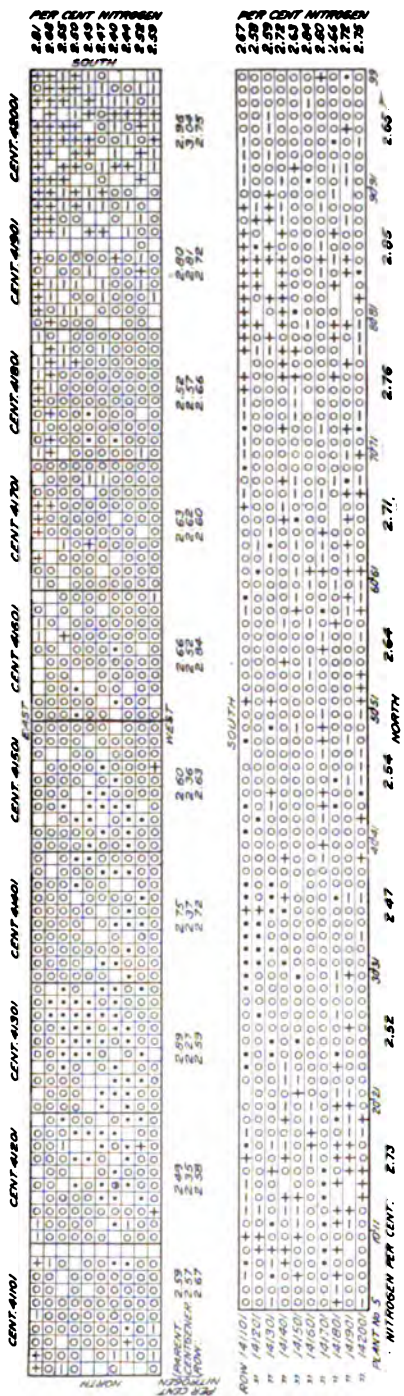


FIG. 6.—Diagram of 10 centgeners and 10 corresponding rows, showing variations in nitrogen content for individual plants, for each centgen, for each corresponding row, and also for their parents. The symbols used are as follows: Blank spaces indicate plants missing; dots, plants analyzing below 2.2 per cent nitrogen; circles, plants analyzing between 2.2 and 2.8 per cent; dashes, plants analyzing between 2.8 and 3 per cent; crosses, plants analyzing, 3 per cent and over.

Figure 6 is a graphic illustration of the centgen and row plats. The soil on which these plats were located was thought to be very uniform, and the appearance of the crop on the various plats was also uniform. The average per cent of nitrogen in the 10 centgeners varied from 2.27 (No. 41301) to 3.04 (No. 42001). To show the location of high and low nitrogen plants in each centgen the method of plotting shown in the figure was used. Where plants were missing the space is left blank; where a plant analyzed less than 2.20 per cent in nitrogen a dot (.) is used; from 2.20 to 2.80 per cent the circle is employed, denoting intermediates; from 2.80 to 3 per cent a dash (—) is used; and all plants analyzing above 3 per cent are marked by a cross (+). The "highs" and "lows" tend to segregate, as in 1907. Also there is a progressive increase toward one end of the series. The 10 duplicate rows are plotted in a similar manner. The rows were more uniform in composition than the centgeners, but they show a variation in composition from 2.58 to 2.84 per cent of nitrogen. Also there seems to be no consistent relation between the rows and the corresponding centgeners, or the parent

plants. The variation in both centgeners and rows seems to be due to local effects, and does not appear to be hereditary. We may eliminate any possibility of hereditary effect by adding together the short rows in the centgeners which come end to end, thus making 10 long rows with each centgener equally represented. The results of such composite analyses are shown at the right of the centgener plat, indicating a variation ranging from 2.40 to 2.81 in percentage of nitrogen in the 10 rows. In the same way we may divide the 10 original rows into blocks having each row equally represented. Variation in the 10 blocks thus formed is shown, at the bottom of figure 6, to be from 2.47 to 2.85 per cent of nitrogen.

RELATION OF YIELD OF GRAIN TO NITROGEN CONTENT.

Since some centgeners yield more grain than others, the 29 centgeners from the same parent plant, of which the 10 centgeners just considered were a part, were arranged according to percentage of nitrogen and summarized in groups of 5 centgeners. This summary (Table V) shows some relation between yield of grain per centgener and nitrogen content, the yield varying inversely with the nitrogen content, but when the 29 corresponding rows were arranged in the same way no such relation was shown.

TABLE V.—*Nitrogen content of 29 centgeners and corresponding rows from family No. 831 in 1908.*

Arranged according to nitrogen in centgeners.							Arranged according to nitrogen in rows.						
Number of centgeners.	Centgener.			Corresponding row.		Nitrogen in parent plants.	Number of rows.	Row.		Corresponding centgener.			Nitrogen in parent plants.
	Nitrogen.	Total yield.	Average yield per plant.	Nitrogen.	Total yield.			Nitrogen.	Total yield.	Nitrogen.	Total yield.	Average yield per plant.	
	P. ct.	Grams.	Grams.	P. ct.	Grams.	Per cent.		P. ct.	Grams.	P. ct.	Grams.	Grams.	P. ct.
5.....	2.83	616	7.19	2.67	194	2.69	5.....	2.78	189	2.63	652	7.52	2.65
5.....	2.63	614	7.13	2.66	200	2.68	5.....	2.72	196	2.57	763	9.03	2.73
5.....	2.56	851	9.60	2.65	173	2.63	5.....	2.65	194	2.52	817	9.14	2.72
5.....	2.52	767	9.01	2.57	179	2.66	5.....	2.60	195	2.57	789	11.13	2.62
5.....	2.44	799	9.01	2.52	189	2.71	5.....	2.55	188	2.55	777	8.72	2.64
4.....	2.34	916	10.50	2.64	209	2.68	4.....	2.35	176	2.50	729	8.50	2.68

TABLE VI.—Nitrogen content and yield of grain from 180 wheat plants, arranged in inverse order of percentage of nitrogen, in groups of 10.

NINETY PLANTS FROM CENTGENER No. 41801.

Plant No.	Nitro- gen.	Yield.	Plant No.	Nitro- gen.	Yield.	Plant No.	Nitro- gen.	Yield.
	Per ct.	Grams.		Per ct.	Grams.		Per ct.	Grams.
52.....	3.44	1.55	64.....	2.62	11.11	27.....	2.43	7.49
79.....	3.22	.60	83.....	2.62	16.23	47.....	2.43	7.11
61.....	3.21	7.86	93.....	2.62	19.49	59.....	2.43	6.60
81.....	3.19	4.36	9.....	2.61	9.16	78.....	2.43	7.39
91.....	3.19	6.45	51.....	2.61	1.20	26.....	2.41	7.48
41.....	3.17	7.92	31.....	2.60	7.00	63.....	2.41	14.83
22.....	3.13	4.89	67.....	2.60	3.11	20.....	2.40	10.37
12.....	3.00	13.42	8.....	2.58	8.22	35.....	2.39	8.82
6.....	2.98	10.65	16.....	2.58	6.45	48.....	2.39	1.44
61.....	2.98	7.54	54.....	2.58	6.76	69.....	2.39	8.40
Average.....	3.15	6.52	Average.....	2.60	8.87	Average.....	2.41	7.99
71.....	2.92	2.46	56.....	2.58	6.61	68.....	2.37	8.00
90.....	2.92	10.52	60.....	2.57	10.56	96.....	2.37	6.07
80.....	2.89	9.14	73.....	2.57	15.31	55.....	2.36	8.30
33.....	2.85	7.69	76.....	2.56	1.34	24.....	2.34	11.07
72.....	2.82	11.75	32.....	2.53	8.42	45.....	2.30	9.59
87.....	2.82	.45	95.....	2.51	12.25	25.....	2.29	13.16
23.....	2.79	11.46	14.....	2.50	17.52	58.....	2.29	8.19
42.....	2.78	6.82	18.....	2.48	11.22	28.....	2.27	7.90
75.....	2.77	7.59	49.....	2.48	6.15	36.....	2.27	8.60
97.....	2.77	4.44	50.....	2.48	4.99	44.....	2.27	6.85
Average.....	2.83	7.43	Average.....	2.52	9.41	Average.....	2.31	8.77
11.....	2.71	11.47	86.....	2.48	10.01	39.....	2.26	8.66
74.....	2.70	6.83	34.....	2.47	21.10	29.....	2.25	9.85
21.....	2.68	10.52	43.....	2.47	11.18	30.....	2.23	9.17
85.....	2.68	6.32	70.....	2.47	13.25	46.....	2.22	7.24
15.....	2.65	5.55	98.....	2.47	6.83	37.....	2.20	10.01
53.....	2.65	14.26	40.....	2.46	12.08	57.....	2.20	14.78
84.....	2.65	7.45	77.....	2.46	8.27	89.....	2.20	13.50
88.....	2.65	5.21	99.....	2.46	12.81	17.....	2.11	10.31
94.....	2.65	16.94	10.....	2.44	2.93	19.....	2.11	10.40
7.....	2.62	9.17	5.....	2.43	16.20	38.....	2.09	6.90
Average.....	2.66	9.47	Average.....	2.46	11.47	Average.....	2.19	10.08

NINETY PLANTS FROM ROW No. 141801.

79.....	3.31	0.84	88.....	2.77	0.56	25.....	2.54	0.87
7.....	3.29	.26	8.....	2.76	1.69	31.....	2.54	1.54
57.....	3.25	.30	18.....	2.76	1.08	40.....	2.54	1.07
11.....	3.20	.35	99.....	2.76	3.41	72.....	2.53	1.72
9.....	3.19	.77	49.....	2.75	1.29	73.....	2.53	2.42
76.....	3.18	.44	46.....	2.74	2.51	77.....	2.52	.10
80.....	3.18	.79	89.....	2.74	1.30	62.....	2.51	.66
5.....	3.17	1.94	15.....	2.71	.53	33.....	2.48	1.62
87.....	3.10	.33	38.....	2.69	.63	35.....	2.48	4.32
14.....	3.09	.96	10.....	2.67	.18	69.....	2.47	2.00
Average.....	3.20	.70	Average.....	2.73	1.32	Average.....	2.51	1.63
83.....	3.09	.30	50.....	2.67	.65	81.....	2.47	1.46
16.....	3.08	.65	32.....	2.66	1.01	95.....	2.47	2.07
17.....	3.07	.79	64.....	2.66	1.21	37.....	2.45	.60
20.....	3.05	.69	93.....	2.66	1.29	39.....	2.45	.81
23.....	3.02	2.37	97.....	2.65	7.76	98.....	2.44	7.10
12.....	3.00	.77	47.....	2.64	.70	41.....	2.43	2.33
21.....	2.99	2.27	78.....	2.64	.45	42.....	2.39	2.74
27.....	2.96	1.59	50.....	2.63	.74	44.....	2.39	2.22
85.....	2.90	1.28	70.....	2.62	.57	58.....	2.39	.86
90.....	2.88	2.02	51.....	2.61	2.01	52.....	2.35	1.12
Average.....	3.00	1.27	Average.....	2.64	1.64	Average.....	2.42	2.13
68.....	2.87	1.42	74.....	2.61	1.07	71.....	2.33	1.39
30.....	2.84	2.34	26.....	2.60	1.18	91.....	2.30	.81
29.....	2.82	1.61	54.....	2.60	.10	61.....	2.29	.20
6.....	2.80	.52	63.....	2.60	.94	48.....	2.25	1.17
60.....	2.80	.24	34.....	2.58	.99	24.....	2.18	.21
55.....	2.79	.88	56.....	2.58	.38	43.....	2.14	1.31
84.....	2.79	1.48	80.....	2.58	.90	36.....	1.99	1.13
22.....	2.77	.65	96.....	2.58	2.50	45.....	1.87	1.07
53.....	2.77	1.92	28.....	2.57	2.16	94.....	1.37	.79
75.....	2.77	.52	67.....	2.56	2.31	19.....	1.33	.47
Average.....	2.80	1.14	Average.....	2.59	1.25	Average.....	2.00	.85

TABLE VI.—*Nitrogen content and yield of grain from 180 wheat plants, arranged in inverse order of percentage of nitrogen, in groups of 10—Continued.*

SUMMARY OF AVERAGES.

Group No.	Groups from cent-gener No. 41801.		Groups from row No. 141801.		Group No.	Groups from cent-gener No. 41801.		Groups from row No. 141801.	
	Nitrogen.	Grain per plant.	Nitrogen.	Grain per plant.		Nitrogen.	Grain per plant.	Nitrogen.	Grain per plant.
	Per cent.	Grams.	Per cent.	Grams.		Per cent.	Grams.	Per cent.	Grams.
1.....	3.15	6.52	3.20	0.70	6.....	2.46	11.47	2.59	1.25
2.....	2.83	7.43	3.00	1.27	7.....	2.41	7.99	2.51	1.63
3.....	2.66	9.47	2.80	1.14	8.....	2.31	8.77	2.42	2.13
4.....	2.60	8.87	2.73	1.32	9.....	2.19	10.08	2.00	.85
5.....	2.52	9.41	2.64	1.64					

The fluctuation in yield between plants within a centgener or row commonly varies as much as 500 per cent. To note whether this wide variation bore any relation to nitrogen content, the results from all the plants in centgener No. 41801 and from its corresponding row were tabulated according to nitrogen content (Table VI). While the summary shows a marked variation in nitrogen content, there is no corresponding change in yield, although there is a slight irregular tendency for yield to increase as nitrogen decreases.

While the foregoing data deal almost entirely with variations under nursery conditions, it would be interesting to know whether such local variations also occur under field conditions. That individual plants vary in this way is without doubt true, as the records of the row plats just cited show. To determine whether local variations were found in field plats, two sets of data were secured in the following manner:

In one of the field plats a drill row 224 feet long was selected and divided into 2-foot sections. The soil was of average fertility and uniformity. The results are shown in Table VIII.

Also a plat of land 77 by 88 feet with a 5-foot margin outside of this was sown to Turkey winter wheat, using a drill 5.5 feet wide. A very uniform stand and quite uniform growth were secured. The plat would have yielded about 30 bushels per acre. At harvest time it was divided into blocks 5.5 feet square, making 224 such blocks. A composite sample was made from the harvest of each block and each sample was analyzed for total nitrogen. Figure 7 is a diagram of this plat, showing the yield of grain and percentage of nitrogen in each block. The same variation is here found that has been noted heretofore in the centgenerns and nursery rows. For example, in the first series of 16 blocks, Nos. 2 and 13 average 1.74 per cent of nitrogen, while Nos. 3 and 8 average 2.07 per cent. This variation seems large in view of the fact that each block has an average of 600 to 800 plants. In this case the variation must be due to some local soil condition. When different numbers of blocks are grouped, the resulting areas are of considerable size, as illustrated by figure 8. The plats shown at B are 11 by 22 feet in area and each was sampled 8 times, yet they show a variation in nitrogen content ranging from 1.81 to 1.97 per cent.

REDUCING THE EXPERIMENTAL ERROR.

So great is the fluctuation in individual plants, due to variation in environment, that there would seem to be no hope of improving the

percentage of nitrogen through the continuous selection of high fluctuates. No cumulative results can be expected where the error is larger than the expected variation.

The problem of finding a high-nitrogen wheat seems to resolve itself into the isolation of pure strains and the comparison of these for nitrogen content. To effect this isolation and comparison, a method must be found that will reduce error to the minimum. Replication according to some systematic method seems the most practical way. A num-

180	183	200	191	190	189	179	175	203	183	218	193	177	186
224	208	192	176	160	144	128	112	96	80	64	48	32	16
180	207	177	190	170	179	190	204	195	183	206	176	186	179
223	207	191	175	159	143	127	111	95	79	63	47	31	15
193	196	183	192	169	190	180	189	183	185	200	213	182	183
222	206	190	174	158	142	126	110	94	78	62	46	30	14
189	196	192	186	179	186	179	194	192	180	197	200	187	173
221	205	189	173	157	141	125	109	93	77	61	45	29	13
200	201	189	177	197	185	197	210	199	183	200	192	179	189
220	204	188	172	156	140	124	108	92	76	60	44	28	12
196	196	200	182	193	182	187	187	192	199	187	183	192	196
219	203	187	171	155	139	123	107	91	75	59	43	27	11
189	211	199	187	186	184	206	190	190	182	181	197	179	189
218	202	186	170	154	138	122	106	90	74	58	42	26	10
203	186	180	186	206	172	186	172	207	182	184	197	196	201
217	201	185	169	153	137	121	105	89	73	57	41	25	9
183	182	182	175	177	172	190	183	190	183	190	185	176	207
216	200	184	168	152	136	120	104	88	72	56	40	24	8
187	214	196	187	197	190	190	213	180	183	190	206	194	187
215	199	183	167	151	135	119	103	87	71	55	39	23	7
190	194	194	177	189	186	182	187	180	184	187	204	194	189
214	198	182	166	150	134	118	102	86	70	54	38	22	6
194	176	196	199	187	204	193	177	174	189	193	196	204	197
213	197	181	165	149	133	117	101	85	69	53	37	21	5
183	199	197	208	199	196	215	182	178	183	198	189	185	187
212	196	180	164	148	132	116	100	84	68	52	36	20	4
185	187	185	182	192	189	213	182	173	183	196	204	186	208
211	195	179	163	147	131	115	99	83	67	51	35	19	3
210	183	185	196	201	192	168	189	185	185	183	185	207	175
210	194	178	162	146	130	114	98	82	66	50	34	18	2
193	186	193	187	190	186	199	189	183	182	196	199	199	206
209	193	177	161	145	129	113	97	81	65	49	33	17	1

FIG. 7.—Diagram of plat of Turkey wheat containing 224 blocks (each 5.5 feet square), showing the location of each block (lower figures) and variations in the percentage of nitrogen in the grain (upper figures).

ber of examples have been worked up from data at hand to illustrate the effect of replication in reducing error.

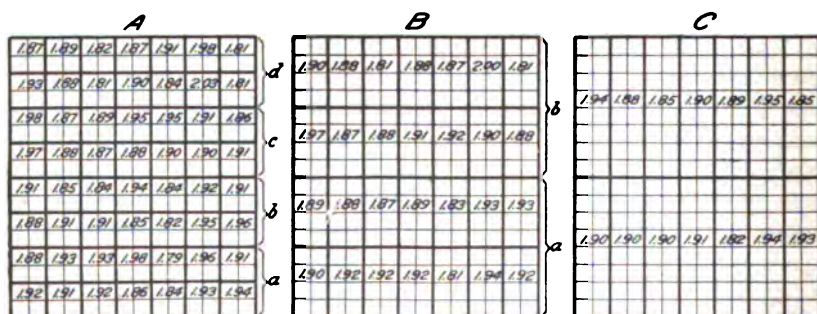


FIG. 8.—Diagrams of plats of Turkey wheat, showing the arrangement of 224 blocks (each 5.5 feet square) when combined in groups of adjacent blocks, with average nitrogen content for each group: A, Groups of 4; B, groups of 8; C, groups of 16.

REPLICATION OF SINGLE PLANTS.

In the first case the 840 centgen plants from the same parent, heretofore referred to (fig. 6), were grouped in various ways. Starting

with the first plant and taking every forty-second plant thereafter gave a composite group of 20 plants. Taking the second and every forty-second thereafter in the same way gave a second group, and so on in the same manner until 42 groups of 20 plants each had been made. In a similar manner 21 groups of 40 plants each were formed. Also, each of the 10 centgeners, being 10 plants square, was formed into 10 rows and the rows numbered 1 to 10. Each row would have 10 plants if the stand were perfect, but in this case it averaged only 8.4 plants per row. By combining the first rows, second rows, etc., in the 10 centgeners, 10 groups were made of 10 rows, or 84 plants each. The results of the above combinations are shown in Table VII. Where 20 plants, uniformly distributed, were combined, the variation in nitrogen content was from 2.40 to 2.67 per cent. Where 40 plants were combined, the variation ranged from 2.47 to 2.60 per cent, but the 10 groups of 10 rows each varied only from 2.49 to 2.59 per cent. Just what should constitute the limits of error in any case will depend on the minimum limit of the variations which are to be detected. In this case 0.1 per cent of nitrogen might be considered such a limit.

TABLE VII.—Nitrogen content of 90 plants of Turkey wheat from 1 centgener and of 840 plants variously combined into groups to show deviation from mean.

90 single plants in 1 centgener (united when having same nitrogen content).						840 single plants variously combined into groups.											
						Combination 1.—Four groups, each composed of every 42d plant in 10 centgeners, or 20 plants.				Combination 2.—Two groups, each composed of every 21st plant in 10 centgeners, or 40 plants.				Combination 3.—A group composed of every 10th row in 10 centgeners or 10 rows, equaling 84 plants.			
Nitrogen.	Frequency.	Deviation.	Nitrogen.	Frequency.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.
P. ct.			P. ct.			P. ct.		P. ct.		P. ct.		P. ct.		P. ct.		P. ct.	
2.09	1	-0.482	2.58	4	+0.008	2.47	-0.043	2.44	-0.089	2.48	-0.044	2.49	-0.042	2.49	-0.042	2.49	-0.042
2.11	2	-0.462	2.60	3	+0.028	2.47	-0.043	2.51	-0.019	2.49	-0.034	2.51	-0.022	2.51	-0.022	2.51	-0.022
2.20	3	-0.372	2.61	2	+0.038	2.48	-0.033	2.51	-0.019	2.50	-0.024	2.52	-0.012	2.52	-0.012	2.52	-0.012
2.22	1	-0.352	2.62	4	+0.048	2.50	-0.013	2.51	-0.019	2.52	-0.004	2.52	-0.012	2.52	-0.012	2.52	-0.012
2.23	1	-0.342	2.65	5	+0.078	2.51	-0.003	2.51	-0.019	2.52	-0.004	2.53	-0.002	2.53	-0.002	2.53	-0.002
2.25	1	-0.322	2.68	2	+0.108	2.51	-0.003	2.51	-0.019	2.53	+0.006	2.53	-0.002	2.53	-0.002	2.53	-0.002
2.26	1	-0.312	2.70	1	+0.128	2.53	+0.017	2.52	+0.009	2.53	+0.006	2.53	-0.002	2.53	-0.002	2.53	-0.002
2.27	3	-0.302	2.71	1	+0.138	2.54	+0.027	2.59	+0.061	2.53	+0.006	2.54	+0.008	2.54	+0.008	2.54	+0.008
2.29	2	-0.282	2.77	2	+0.198	2.54	+0.027	2.59	+0.061	2.55	+0.036	2.56	+0.028	2.56	+0.028	2.56	+0.028
2.30	1	-0.272	2.78	1	+0.208	2.58	+0.067	2.60	+0.071	2.59	+0.066	2.59	+0.058	2.59	+0.058	2.59	+0.058
2.34	1	-0.232	2.79	1	+0.218												
2.36	1	-0.212	2.82	2	+0.248	2.513	.0276	2.529	.0386	2.524	.023	2.532	.0188	2.532	.0188	2.532	.0188
2.37	3	-0.202	2.85	1	+0.278												
2.39	3	-0.182	2.89	1	+0.318	2.46	-0.092	2.40	-0.128	2.47	-0.07						
2.40	1	-0.172	2.92	2	+0.348	2.51	-0.042	2.48	-0.048	2.48	-0.06						
2.41	2	-0.162	2.98	2	+0.408	2.52	-0.032	2.50	-0.028	2.48	-0.06						
2.43	5	-0.142	3.00	1	+0.428	2.52	-0.032	2.52	-0.008	2.50	-0.04						
2.44	1	-0.132	3.13	1	+0.558	2.54	-0.012	2.53	+0.002	2.53	-0.01						
2.46	3	-0.112	3.17	1	+0.598	2.54	-0.012	2.54	+0.012	2.53	-0.01						
2.47	4	-0.102	3.19	2	+0.618	2.54	-0.012	2.54	+0.012	2.54	.00						
2.48	2	-0.092	3.21	1	+0.638	2.58	+0.028	2.56	+0.032	2.54	.00						
2.50	1	-0.072	3.22	1	+0.648	2.64	+0.088	2.56	+0.032	2.56	+0.02						
2.51	1	-0.062	3.44	1	+0.868	2.67	+0.118	2.57	+0.042	2.60	+0.06						
2.53	1	-0.042						2.57	+0.042	2.61	+0.07						
2.56	1	-0.012	2.572		.214	2.552	.0468	2.58	+0.052								
2.57	2	-0.002						2.528	.0365	2.54	.0364						

Where the plants were repeated 20 and 40 times the error was almost what we might reasonably expect the actual variation in pure strains to be, but where 10 centgener rows, or 84 plants, were combined the extreme error was within bounds. The data would indicate that single plants would have to be replicated nearly 100 times to bring the variation within the limits of error.

REPLICATION OF 2-FOOT ROWS.

Table VIII illustrates the variation to be expected by replicating 2-foot rows. For these data a single 220-foot drill row in the general wheat field was divided into 2-foot sections and a composite sample made of each section. The sections were combined in two different ways. The first combination was composed of every twenty-second section, making 22 groups of 5 sections each, and the second combination was composed of every eleventh section, making 11 groups of 10 sections each.

Here, again, the extremes are rather wide, but if these are excluded the results would be called satisfactory. If a comparison of pure strains of wheat was being made under similar conditions, it would be necessary to take for further trial the entire best half of the strains tested in order to be within the limit of error. (See p. 30 and fig. 9.)

TABLE VIII.—*Nitrogen content of 110 2-foot sections of drill row of Turkey wheat, arranged in order of percentage of nitrogen and also in groups of 5 and 10, to show deviation from mean.*

Single 2-foot rows (those with same nitrogen content united).						Five rows in a group composed of every 22d row.		Ten rows in a group composed of every 11th row.	
Nitro- gen.	Fre- quency.	Devia- tion.	Nitro- gen.	Fre- quency.	Devia- tion.	Nitro- gen.	Devia- tion.	Nitro- gen.	Devia- tion.
<i>Per cent.</i>			<i>Per cent.</i>			<i>Per cent.</i>		<i>Per cent.</i>	
1.76	1	—0.271	2.04	5	+0.009	1.91	—0.109	1.96	—0.069
1.79	1	— .241	2.05	2	+ .019	1.96	— .059	1.98	— .049
1.81	1	— .221	2.06	4	+ .029	2.01	— .009	1.98	— .049
1.85	1	— .181	2.07	5	+ .039	2.01	— .009	2.00	— .029
1.86	2	— .171	2.08	4	+ .049	2.01	— .009	2.02	— .009
1.87	1	— .161	2.09	3	+ .059	2.02	+ .001	2.03	+ .001
1.88	1	— .151	2.10	6	+ .069	2.02	+ .001	2.04	+ .011
1.89	1	— .141	2.11	1	+ .079	2.03	+ .011	2.06	+ .031
1.90	1	— .131	2.12	2	+ .089	2.06	+ .041	2.06	+ .031
1.91	1	— .121	2.13	2	+ .099	2.09	+ .071	2.06	+ .031
1.92	7	— .111	2.14	3	+ .109	2.09	+ .071	2.13	+ .101
1.93	5	— .101	2.15	1	+ .119				
1.95	5	— .081	2.16	1	+ .129	2.019	.0355	2.029	.0374
1.96	3	— .071	2.17	1	+ .139				
1.97	2	— .061	2.19	2	+ .159	1.96	— .077		
1.98	5	— .051	2.20	3	+ .169	1.98	— .057		
1.99	2	— .041	2.26	4	+ .229	1.99	— .047		
2.00	4	— .031	2.28	1	+ .249	1.99	— .047		
2.01	7	— .021	2.37	1	+ .339	2.03	— .007		
2.02	2	— .011				2.03	— .007		
2.03	6	— .001	2.031		+ .093	2.04	+ .003		
						2.05	+ .013		
						2.06	+ .043		
						2.09	+ .053		
						2.17	+ .133		
						2.037	.0443		

REPLICATION OF 16-FOOT ROWS.

Since 16-foot rows are frequently used as test plats, a determination was made of the variation in a series of these. One hundred check plats from the 1909 field nursery were grouped by fives and tens in the same manner as in the two cases just cited. The results are shown in Table IX. The coefficient of variability and also the extreme variation are less than in the cases just considered.

TABLE IX.—*Nitrogen content of 100 16-foot rows of Turkey wheat, all from the same seed, arranged singly in order of percentage of nitrogen and also in groups of 5 and 10, to show deviation from mean.*

Single 16-foot rows (those with same nitrogen content united).						Five rows in a group composed of every 20th row.		Ten rows in a group composed of every 10th row.	
Nitro- gen.	Fre- quency.	Devia- tion.	Nitro- gen.	Fre- quency.	Devia- tion.	Nitro- gen.	Devia- tion.	Nitro- gen.	Devia- tion.
<i>Per cent.</i>			<i>Per cent.</i>			<i>Per cent.</i>		<i>Per cent.</i>	
1.82	1	-0.316	2.18	6	+0.044	2.09	-0.066	2.10	-0.037
1.86	2	-.276	2.20	1	+.064	2.11	-.036	2.11	-.027
1.87	1	-.266	2.21	1	+.074	2.13	-.016	2.12	-.017
1.89	1	-.246	2.22	4	+.064	2.13	-.016	2.13	-.007
1.92	2	-.216	2.23	1	+.094	2.13	-.016	2.14	+.003
1.93	2	-.206	2.25	2	+.114	2.14	-.006	2.14	+.003
1.94	1	-.196	2.27	2	+.124	2.16	+.014	2.15	+.013
1.96	3	-.176	2.28	2	+.144	2.17	+.024	2.15	+.013
1.97	2	-.166	2.29	3	+.154	2.19	+.044	2.15	+.013
1.99	1	-.146	2.31	3	+.174	2.21	+.064	2.18	+.043
2.00	3	-.136	2.34	2	+.204				
2.01	1	-.126	2.35	1	+.214	2.146	.0202	2.137	.0176
2.03	5	-.106	2.36	1	+.224				
2.04	3	-.096	2.38	1	+.244	2.07	-.068		
2.06	6	-.076	2.42	1	+.284	2.08	-.048		
2.07	2	-.066	2.43	1	+.294	2.09	-.038		
2.08	6	-.056	2.45	1	+.314	2.09	-.038		
2.10	3	-.036	2.48	1	+.344	2.10	-.028		
2.11	2	-.026	2.50	1	+.364	2.13	+.002		
2.13	7	-.006	2.52	1	+.384	2.17	+.042		
2.14	2	+.004				2.18	+.052		
2.15	4	+.014	2.136		.1178	2.18	+.052		
2.17	4	+.034				2.19	+.062		
						2.128	.0420		

Where the 16-foot rows were repeated 10 times the extreme difference in nitrogen content was only 0.08 per cent. To further test this question, 500 rows, each 16 feet in length, were planted in the fall of 1909 under quite uniform conditions. These rows were harvested and combined in groups of 5, 10, 15, and 20, as in the previous case. The results are summarized at the bottom of Table X. When the rows are repeated only 5 times the error is too wide for satisfactory results, but when repeated 10 times the error is small enough for experimental purposes. Repeating 15 and 20 times gave only a small further reduction in variation.

A point of interest is the fact that in 1909, where rows were repeated 5 or 10 times, the experimental error was less than it was in 1910. In fact, there is no way of establishing a set rule as to the number of repetitions necessary, since the experimental error is influenced by

all the factors affecting the growth of plants, such as soil fertility, climate, or insects. In order to know what this error is in a particular case it would be advisable to grow a sufficient number of check plats in each system of plats to determine the error by actual test.

Table X is a summary of results with the systematic repetition of plants and rows. The column under "Coefficient of variability" shows that repeating 20 single plants in a systematic way has given about as great accuracy in determining nitrogen content as 2-foot rows repeated 10 times or 16-foot rows repeated 5 times. For determining comparative nitrogen content, repeating single plants 20 to 40 times in a systematic method seems to give quite satisfactory results.

TABLE X.—Summary showing degree of error due to variation in environment, according to several methods of comparison.

Classification.	Number of groups.	Mean nitrogen content.	Extreme variation.	Average deviation.	Standard deviation.	Coefficient of variability.
		<i>Per cent.</i>				<i>Per cent.</i>
90 single plants (Table VII).....	90	2.572	2.09-3.44	0.2140	0.279	10.85
840 single plants (Table VII):						
Every 42d plant, 20 plants in a group.....	a 10 b 10 c 10 d 12	2.513 2.552 2.529 2.528	2.47-2.58 2.46-2.67 2.44-2.60 2.40-2.58	.0276 .0468 .0386 .0365	.0335 .0592 .0473 .0484	1.33 2.32 1.87 1.91
Average.....	10.5	2.531	2.44-2.61	.0374	.0471	1.86
Every 21st plant, 40 plants in a group.....	a 10 b 11	2.524 2.540	2.48-2.59 2.47-2.61	.0230 .0364	.0307 .0455	1.22 1.17
Average.....	10.5	2.532	2.47-2.60	.0297	.0381	1.50
As 10 centgeners, every 10th cent- gener row, 10 rows in a group.....	10	2.532	2.49-2.59	.0188	.0260	1.03
110 2-foot rows, single rows (Table VIII).	110	2.031	1.76-2.37	.093	.1087	5.35
Every 22d row, 5 rows in a group.....	a 11 b 11	2.019 2.037	1.91-2.09 1.96-2.17	.0355 .0443	.0499 .0574	2.47 2.82
Average.....	11	2.028	1.94-2.13	.0390	.0537	2.65
Every 11th row, 10 rows in a group..	11	2.029	1.96-2.13	.0374	.0464	2.28
100 16-foot rows (Table IX).....	100	2.136	1.82-2.52	.1178	.1492	6.98
Every 20th row, 5 rows in a group.....	a 10 b 10	2.146 2.128	2.09-2.21 2.07-2.19	.0292 .0420	.0347 .0451	1.62 2.12
Average.....	10	2.137	2.08-2.20	.0356	.0399	1.87
Every 10th row, 10 rows in a group..	10	2.137	2.10-2.18	.0176	.0219	1.02
500 16-foot rows (in 1910):						
Single rows.....		1.905	1.68-2.28	.0839	.1060	5.67
Every 100th row, 5 rows in a group..	a 25 b 25 c 25 d 25	1.904 1.917 1.908 1.890	1.81-1.99 1.84-2.02 1.81-2.03 1.81-1.98	.0393 .0376 .0403 .0388	.0469 .0469 .0502 .0488	2.46 2.45 2.63 2.42
Average.....		1.905	1.82-2.00	.0379	.0474	2.49
Every 50th row, 10 rows in a group..	a 25 b 25	1.908 1.902	1.83-1.96 1.83-1.96	.0273 .0266	.0329 .0343	1.72 1.80
Every 33d row, 15 rows in a group.....		1.903	1.86-1.96	.0235	.0276	1.45
Every 25th row, 20 rows in a group.....		1.905	1.85-1.96	.0190	.0242	1.27

2.47-2.58

2.46-2.67

2.44-2.60

2.40-2.58

THE SMALL-BLOCK TEST.

Figure 7 (p. 22) illustrates the method of making the small-block test and also shows the percentage of nitrogen in the grain from each block. Table XI shows the result of repeating these blocks 4, 8, and 16 times in a systematic method, i. e., taking every fifty-sixth, twenty-eighth, or fourteenth block (fig. 8). The experimental error varied inversely with the number of repetitions, but was only within the limit of error when the repetition was 16 times.

TABLE XI.—*Nitrogen content of Turkey wheat grown in 224 block plats (each 5.5 feet square) in 1909 and 1910.*

SYSTEMATICALLY REPEATED TO FORM GROUPS OF 4, 8, AND 16 BLOCKS.

Four blocks in a group composed of every 56th block.				Eight blocks in a group composed of every 28th block.		Sixteen blocks in a group composed of every 14th block.	
Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.	Nitrogen.	Deviation.
<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>	
1.78	−0.128	1.81	−0.115	1.82	−0.086	1.84	−0.06
1.84	−.068	1.85	−.075	1.87	−.046	1.86	−.04
1.85	−.058	1.87	−.055	1.88	−.036	1.87	−.03
1.88	−.028	1.87	−.055	1.90	−.018	1.87	−.03
1.89	−.018	1.90	−.025	1.90	−.016	1.89	−.01
1.90	−.008	1.93	+ .005	1.90	−.016	1.90	+ .00
1.91	+ .002	1.93	+ .005	1.92	+ .004	1.90	+ .00
1.91	+ .002	1.96	+ .035	1.92	+ .004	1.91	+ .01
1.93	+ .022	1.96	+ .035	1.94	+ .024	1.91	+ .01
1.93	+ .022	1.96	+ .035	1.94	+ .024	1.92	+ .02
1.94	+ .032	1.96	+ .035	1.94	+ .024	1.92	+ .02
1.95	+ .042	1.97	+ .045	1.95	+ .034	1.93	+ .03
1.96	+ .072	1.97	+ .045	1.95	+ .034	1.94	+ .04
2.02	+ .112	2.01	+ .085	1.99	+ .074	1.94	+ .04
Average..1.908	.0439	1.925	.0464	1.916	.032	1.90	.024
1.83	−.041	1.80	−.094	1.83	−.051		
1.83	−.041	1.86	−.034	1.85	−.031		
1.83	−.041	1.87	−.024	1.86	−.021		
1.84	−.031	1.87	−.024	1.86	−.021		
1.84	−.031	1.87	−.024	1.86	−.021		
1.85	−.021	1.88	−.014	1.87	−.011		
1.85	−.021	1.89	−.004	1.88	−.001		
1.86	−.011	1.90	+ .006	1.88	−.001		
1.87	−.001	1.90	+ .006	1.88	−.001		
1.87	−.001	1.90	+ .006	1.89	+ .011		
1.88	+ .009	1.90	+ .006	1.90	+ .021		
1.94	+ .069	1.90	+ .006	1.92	+ .041		
1.95	+ .079	1.94	+ .046	1.92	+ .041		
1.95	+ .079	2.04	+ .146	1.93	+ .051		
Average..1.871	.034	1.894	.0314	1.881	.0231		

TABLE XI.—*Nitrogen content of Turkey wheat grown in 224 block plats (each 5.5 feet square) in 1909 and 1910—Continued.*

COMBINED IN GROUPS OF 4, 8, AND 16 ADJACENT BLOCKS, TO SHOW THE EFFECT OF SIZE OF PLAT ON VARIABILITY.

Four sets of 14 groups, with 4 adjacent blocks in each group.						Two sets of 14 groups, with 8 adjacent blocks in each group.			One set of 14 groups, with 16 adjacent blocks in each group.			
Nitrogen.	Deviation.	Standard deviation.	Nitrogen.	Deviation.	Standard deviation.	Nitrogen.	Deviation.	Standard deviation.	Nitrogen.	Deviation.	Standard deviation.	
<i>Per cent.</i>			<i>Per ct.</i>			<i>Per ct.</i>			<i>Per ct.</i>			
1.79	-0.117		1.86	-0.05		1.81	-0.066		1.82	-0.077		
1.84	-.067		1.87	-.04		1.83	-.066		1.85	-.047		
1.86	-.047		1.87	-.04		1.87	-.026		1.85	-.047		
1.88	-.027		1.88	-.03		1.88	-.016		1.88	-.017		
1.91	+.003		1.88	-.03		1.89	-.006		1.89	-.007		
1.91	+.003		1.89	-.02		1.89	-.006		1.90	+.003		
1.92	+.013		1.90	-.01		1.90	+.004		1.90	+.003		
1.92	+.013		1.90	-.01		1.92	+.024		1.90	+.003		
1.93	+.023		1.91	0		1.92	+.024		1.90	+.003		
1.93	+.023		1.91	0		1.92	+.024		1.91	+.013		
1.93	+.023		1.95	+.04		1.92	+.024		1.93	+.033		
1.94	+.033		1.95	+.04		1.93	+.034		1.94	+.043		
1.96	+.053		1.97	+.06		1.93	+.034		1.94	+.043		
1.98	+.073		1.98	+.07		1.94	+.044		1.95	+.053		
Average..	1.907	.037	0.048	1.91	.0314	0.0376	1.896	.0299	0.0372	1.897	.028	0.0363
1.82	-.072					1.81	-.081					
1.84	-.052		1.81	-.072		1.81	-.081					
1.84	-.052		1.81	-.072		1.87	-.021					
1.85	-.042		1.81	-.072		1.87	-.021					
1.85	-.042		1.82	-.062		1.88	-.011					
1.88	-.012		1.84	-.042		1.88	-.011					
			1.87	-.012								
1.91	+.018		1.87	-.012		1.88	-.011					
1.91	+.018		1.88	-.002		1.88	-.011					
1.91	+.018		1.89	+.008		1.90	+.009					
1.91	+.018		1.90	+.018		1.90	+.009					
1.92	+.028		1.91	+.028		1.91	+.019					
1.94	+.048		1.93	+.048		1.92	+.029					
1.95	+.058		1.98	+.098		1.97	+.079					
1.96	+.068		2.03	+.148		2.00	+.109					
Average..	1.892	.0390	.0436	1.882	.0496	.0636	1.891	.0358	.0492			

TABLE XI.—*Nitrogen content of Turkey wheat grown in 224 block plats (each 5.5 feet square) in 1909 and 1910—(continued).*

SUMMARY SHOWING EXPERIMENTAL ERROR WHEN BLOCKS ARE ASSEMBLED IN VARIOUS WAYS.

Classification.	Number of groups.	Season of 1909.					Season of 1910.				
		Mean nitrogen content.	Extreme variation.	Average deviation.	Standard deviation.	Coefficient of variability.	Mean nitrogen content.	Extreme variation.	Average deviation.	Standard deviation.	Coefficient of variability.
Systematically repeated..	1	P. ct. 1.898	1.68-2.18	0.0786	0.0081	5.17	1.868	1.66-2.24	0.0692	0.8987	4.81
Every 56th block, 4 blocks in a group...	a 14	1.908	1.78-2.02	.0439	.0579	3.03	1.852	1.81-1.89	.0250	.0274	1.50
	b 14	1.871	1.83-1.95	.0340	.0425	2.27	1.850	1.79-1.91	.0310	.0342	1.85
	c 14	1.925	1.81-2.01	.0464	.0546	2.84	1.871	1.81-1.92	.0259	.0316	1.69
	d 14	1.894	1.80-2.04	.0314	.0503	2.61	1.885	1.82-2.04	.0386	.0532	2.82
Average.....	14	1.90	1.80-2.00	.0389	.0513	2.69	1.865	1.81-1.94	.0289	.0347	1.96
Every 28th block, 8 blocks in a group...	a 14	1.916	1.82-1.99	.0320	.0438	2.29	1.863	1.83-1.89	.0143	.0167	.89
	b 14	1.881	1.83-1.93	.0231	.0287	1.53	1.899	1.83-1.91	.0184	.0226	1.21
Average.....	14	1.90	1.82-1.96	.0275	.0362	1.91	1.866	1.83-1.90	.0163	.0196	1.05
Every 14th block, 16 blocks in a group...	14	1.90	1.84-1.94	.0240	.0295	1.55	1.864	1.84-1.88	.0123	.013	.72
Adjacent groups:											
Four blocks in a group	a 14	1.907	1.79-1.98	.0370	.0480	2.52	1.929	1.80-2.02	.0503	.0612	3.17
	b 14	1.892	1.82-1.96	.0390	.0436	2.31	1.871	1.79-1.96	.0400	.0484	2.59
	c 14	1.910	1.86-1.98	.0314	.0376	1.93	1.841	1.78-1.92	.0301	.0368	2.00
	d 14	1.882	1.81-2.03	.0496	.0636	3.31	1.817	1.77-1.89	.0261	.0319	1.76
Average.....	14	1.894	1.82-1.99	.0442	.0482	2.54	1.865	1.78-1.95	.0368	.0436	2.38
Eight blocks in a group	a 14	1.896	1.81-1.94	.0299	.0372	1.96	1.901	1.82-1.98	.0444	.0504	2.65
	b 14	1.891	1.81-2.00	.0358	.0492	2.60	1.829	1.79-1.89	.0263	.0299	1.63
Average.....	14	1.894	1.81-1.97	.0328	.0432	2.28	1.865	1.80-1.93	.0353	.0401	2.14
Sixteen blocks in a group.....	14	1.897	1.82-1.95	.028	.0363	1.91	1.866	1.80-1.96	.0403	.0464	2.49

In 1910 the same set of blocks was again in wheat, and they were again grouped in the same way, exactly the same plats being combined each year. The experimental error was less in 1910 than in 1909, and repeating the blocks 8 times gave total variations ranging from 1.83 to 1.90 per cent, which is well within the experimental limit. It appears that repeating the plats in this particular case 8 times in 1910 gave as good results as repeating 16 times in 1909; in fact, repeating 4 times would have been almost as satisfactory. In the case of the 16-foot rows just described the error was least in 1909, while the reverse was true in regard to the error in the blocks. This result again illustrates the point, made in discussing the row tests, that sufficient check plats must be used in order to know the experimental error in any particular case.

INCREASING THE SIZE OF PLAT.

Table XI also illustrates the effect of increasing the size of the plat. While such increase ought theoretically to reduce error from the standpoint of increasing the number of plants and including a larger

number of local soil variations, yet an equal number of large plats reach over into new territory and include new causes for variation. To secure a practical illustration the 224 small blocks were combined into several series of larger plats by adding together adjacent plats. This method is illustrated in figure 8 (p. 22), and the statistical data are given in Table XI, a study of which shows that increasing the size above four adjacent blocks does not decrease the variability. In comparing systematic replication (Table X) with increase in size of plat it will be seen that the former constantly decreases variation, and would so continue to infinity, while the latter would not be controlled by such a law. It has been noted that the degree of variability was not the same when similar data were collected from different fields or in different years.

Variation is not a constant factor even where conditions are quite uniform, as is illustrated by the four sets of 14 groups composed of four adjacent plats. The fluctuation of extremes is almost twice as great in the fourth set as in the third.

The foregoing data can not be taken as a strict comparison of the different methods, as the data in each case were secured under somewhat different conditions. They are mainly valuable in illustrating the expected variation when different methods of comparison are used. It is evident that, whatever the method used, a single plat or duplicate plats can not be relied on for determining the actual nitrogen content of a strain or variety of wheat. The plats must be repeated 5 to 15 times, depending on uniformity of conditions and accuracy of results desired. In addition, at least a few series of check plats should be included in order to determine the experimental error as a guide to accuracy of results.

Our experience so far indicates that the simplest and most accurate method is to use 16-foot rows, replicated 10 times, with a check plat every 5 or 10 rows.

THE LIMIT OF EXPERIMENTAL ERROR.

The above examples give some indication of the experimental error to be expected by the different methods. Since the experimental error depends upon the variation in environmental conditions, it is possible that conditions might be found so ideal that there would be practically no experimental error; also that under other conditions it might be greater than in the cases just cited. In all cases the experimental error should be determined by the use of check plats. With this factor known it will be possible to decide on some plan of selection. Figure 9 illustrates an ideal case where the experimental error is known. Suppose that in 10 strains of wheat being tested by the row method with check plats, the highest should

average 3 per cent of nitrogen and the lowest 2 per cent of nitrogen, the remainder being distributed between. Suppose a series of checks, repeated in the same way as the tested strains, showed a variation of 2.2 per cent to 2.6 per cent, with a mean of 2.4 per cent. This would give an experimental error of 0.2 per cent; that is, a certain strain might be 0.2 per cent higher than it should be or 0.2 per cent lower than it should be. Let the line *ab* indicate the variation in nitrogen content obtained in the 10 strains under test. If the experimental error equaled 0.2 per cent, then No. 1 might equal either 3.2 per cent or 2.8 per cent, and in the same way a strain analyzing 2.6 per cent might possibly be either 2.8 per cent or 2.4 per cent. In other words, the strain analyzing 2.6 per cent might be just as good as the one analyzing 3 per cent. Therefore, if the experimental error has been determined, the rule would be to double the error and subtract this sum from the highest variant. The remainder after subtraction would represent the nitrogen content below which all strains could be discarded without danger of discarding a high-nitrogen strain. (The same method applies to the use of experimental error in selecting for yield.) In the case illustrated in figure 9, all strains analyzing above 2.6 per cent must be selected for further test to be sure that one of the best is not being left. If the experimental error equals one-half the real variations in strains compared, then no selection can be made, but all the strains must be retested.

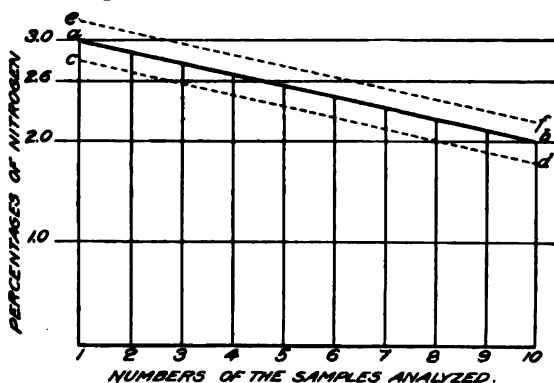


FIG. 9.—Diagram showing the method of selection for nitrogen content when the experimental error is known.

cent must be selected for further test to be sure that one of the best is not being left. If the experimental error equals one-half the real variations in strains compared, then no selection can be made, but all the strains must be retested.

SUMMARY.

(1) Wheat plants growing under field conditions or nursery conditions show great variation in nitrogen content. This variation, however, does not seem to be inherited but is apparently due to local variation in environment and is therefore not capable of transmission.

(2) Centgeners, rows, and small plats vary almost as much as individual plants, owing to local variation in environment.

(3) The most practical way of overcoming this variation is by replicating the plats a sufficient number of times to reduce the error to less than one-half the real variation.

(4) To bring the experimental error within proper bounds, single plants should be repeated 40 or more times, 16-foot rows 5 to 10 times, and blocks 5.5 feet square 8 to 16 times. No data are given for centgeners, but the variation in centgeners is about the same as in the blocks.

(5) In order to eliminate the undesirable strains, the experimental error must be less than one-half the real or expected variation.

(6) The easiest and most practical method of growing strains to compare for nitrogen content is to plant in rows 12 to 16 feet in length and repeat 10 times in different parts of the field. Several series of check plats should also be inserted.

II.—EXPERIMENTAL ERROR IN THE NURSERY AND VARIATION IN YIELD

INTRODUCTION.

A very large share of cereal breeding to-day consists in the separation of pure strains from what we call our ordinary varieties of cereals. In dealing with new hybrids the separation involves the selection of the most desirable strains after types have been fixed. We are mainly concerned for the present in finding the best-yielding strains. This necessitates the finding of a method by which comparative field tests can be made rapidly in large numbers.

The method of comparing strains in "centgeners" first came into general use some 10 years ago, and later the "row" method was evolved. At present the Nebraska Agricultural Experiment Station is experimenting with a small block similar in size to the centgener, but sown at the ordinary rate of seeding.

A number of sources of error in all these methods are due to unexpected variations in soil and climate. It is the purpose of this paper to discuss some of these sources of error and to suggest methods of correction.

VARIATION IN YIELD FROM CHECK ROWS.

In our row-breeding work we use every fifth row as a check plat. All check plats are from the same seed and sown in the same way. A great variation is found in these check rows even when conditions appear quite uniform. Table XII shows the yield of 47 consecutive check rows in one of the 1909 series. These rows were 14 feet long and each was hand planted with 400 seeds of Turkey wheat. They were not quite as uniform as we sometimes have them, owing to dry weather in the spring, although the appearance of the plats was uniform enough at harvest time. One object in presenting the data here, however, is to illustrate the effect of repeating check plats on correction of error. All things being equal, the yields of the 47 plats should have been the same. But all factors can never be equal, so in row-breeding work, owing to unequal environment, we must expect a wide degree of error. The only practical way so far suggested to overcome this error is to repeat the plats, according to some systematic method, enough times to equalize variations in soil or climatic effects. If the plats are repeated only a few times there is

still danger of a large error due to the chance combination of plats unduly high or low. This is illustrated by data given in the lower half of Table XII, where all the above check rows have been brought together in groups of six each (except group *h*), taking every eighth plat to form a group, to show the chance of error in repeating a series of strains six times.

TABLE XII.—Yield of 47 14-foot check plats of Turkey wheat in 1909.

CHECK PLATS IN CONSECUTIVE ORDER.

Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
205	239	162	165	182	205	216	230
170	240	204	279	265	270	278	310
202	167	200	238	285	265	222	238
247	216	225	284	255	265	279	155
304	272	226	237	245	150	268	186
209	310	278	347	168	306	239	

CHECK PLATS SYSTEMATICALLY REPEATED TO FORM EIGHT GROUPS.

Group a.	Group b.	Group c.	Group d.	Group e.	Group f.	Group g.	Group h.
Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
205	170	202	247	304	209	239	240
167	216	272	310	182	204	200	225
226	278	165	280	238	284	237	347
182	265	285	255	245	168	205	270
265	265	150	306	216	278	222	280
268	239	230	310	238	155	186	.....
219	239	217	285	214	216	215	272

Groups arranged in order of average yield of included plats: *g*, 215; *f*, 216; *c*, 217; *a*, 219; *e*, 234; *b*, 239; *h*, 272; *d*, 285. Average, 237.

Groups *a* and *d* illustrate the chance grouping of high-yielding and low-yielding plats. With only 5 plats out of the 47 yielding above 300 grams, three of them by chance fell into group *d* while a number below normal fell into group *a*. The average yields of the 8 groups varied from 215 grams to 285 grams. This variation indicates the amount of experimental error to be expected under similar conditions. Since the experimental error is larger than the real variation expected in different strains of wheat, results obtained under such circumstances would not be reliable. Until our system of testing will show actual differences of 10 per cent in yield, it can not be of much value in comparing the yielding value of different strains.

VARIATION IN YIELD FROM REPEATED ROWS.

In order to make a more careful test of the accuracy of replicating row tests, 100 rows of Kherson oats were planted, each row being 12.5 feet in length and containing 500 seeds. The plat chosen for this test was quite uniform and the appearance of the plat at harvest was very satisfactory. Three-fourths of the rows yielded from 225 to 275 grams each, with a few much higher and a few very low. Table XIII shows these rows arranged in consecutive order as they were

in the nursery, with the yield of each row and the average yield of groups of five adjacent rows.

We may get some idea of how replication corrects error by assembling these rows into series as in the comparative test of strains. These data are shown and also summarized in Table XIII. In series 1 the yields of 5 adjacent rows are averaged (as rows 1 to 5, 6 to 10, etc.). In series 2 every twentieth row is taken (as rows 1-21-41-61-81, etc.) and averaged. In series 3 every tenth row is taken, making 10 repetitions; and in series 4 every fifth row, making 20 repetitions.

TABLE XIII.—Yield of thrashed grain from 100 rows of *Kherson oats*.

BY ROWS AND GROUPS OF FIVE ADJACENT ROWS IN CONSECUTIVE ORDER.

Row No.	Yield of grain.		Row No.	Yield of grain.		Row No.	Yield of grain.		Row No.	Yield of grain.	
	Actual.	Mean of 5 rows.		Actual.	Mean of 5 rows.		Actual.	Mean of 5 rows.		Actual.	Mean of 5 rows.
	Grams.	Grams.		Grams.	Grams.		Grams.	Grams.		Grams.	Grams.
1	228	236	26	252	246	51	244	250	76	233	225
2	273		27	248		52	261		77	247	
3	255		28	206		53	258		78	211	
4	224		29	280		54	244		79	237	
5	204		30	247		55	245		80	200	
6	205	224	31	257	235	56	248	221	81	248	222
7	230		32	240		57	229		82	200	
8	260		33	233		58	211		83	227	
9	195		34	230		59	227		84	220	
10	233		35	217		60	188		85	214	
11	257	248	36	226	220	61	248	263	86	194	234
12	243		37	190		62	257		87	233	
13	250		38	222		63	270		88	244	
14	230		39	261		64	264		89	241	
15	261		40	200		65	275		90	270	
16	235	255	41	246	254	66	300	216	91	241	242
17	273		42	249		67	151		92	174	
18	273		43	276		68	153		93	247	
19	263		44	237		69	205		94	266	
20	230		45	261		70	272		95	281	
21	244	234	46	267	249	71	194	235	96	240	247
22	245		47	259		72	274		97	232	
23	209		48	252		73	242		98	228	
24	247		49	251		74	235		99	290	
25	224		50	218		75	229		100	245	

SYSTEMATICALLY GROUPED IN VARIOUS WAYS TO SHOW EFFECT OF REPLICATION ON REDUCTION OF VARIATION IN YIELD.

Series 1.—Groups of 5 adjacent rows.				Series 2.—Groups of 5 rows, taking every 20th row.				Series 3.—Groups of 10 rows, taking every 10th row.		Series 4.—Groups of 20 rows, taking every 5th row.	
Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.	Yield.	Deviation.
Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
216	-21.8	236	-1.8	212	-25.8	239	+1.2	226	-11.8	234	-3.8
220	-17.8	242	+4.2	223	-14.8	231	+3.2	229	-8.8	235	-2.8
221	-16.8	246	+8.2	224	-13.8	242	+4.2	230	-7.8	238	+2.2
222	-15.8	247	+9.2	229	-8.8	242	+4.2	237	-8	241	+3.2
224	-13.8	248	+10.2	234	-3.8	243	+5.2	238	+2	241	+3.2
225	-12.8	249	+11.2	234	-3.8	246	+8.2	239	+1.2		
234	-3.8	250	+12.2	234	-3.8	246	+8.2	241	+3.2		
234	-3.8	254	+16.2	236	-1.8	248	+10.2	243	+5.2		
235	-2.8	255	+17.2	237	-8	245	+17.2	245	+7.2		
235	-2.8	263	+25.2	238	+2	256	+18.2	250	+12.2		
Average....		237.8	11.4			237.8	7.9	237.8	5.8	237.8	2.6

TABLE XIII.—Yield of thrashed grain from 100 rows of Kherson oats—Continued.

SUMMARY SHOWING COMPARISON OF GROUPINGS.

Number of rows in a group.	Average deviation from mean yield when rows are—		Coefficient of variability when rows are—		Variation of extremes in yield when rows are—	
	Adjacent.	Distributed.	Adjacent.	Distributed.	Adjacent.	Distributed.
	Grams.	Grams.	Per cent.	Per cent.	Grams.	Grams.
1.....	21.26	21.26	11.5	11.5	151 to 300	151 to 300
5.....	11.38	7.87	5.50	4.8	216 to 263	212 to 256
10.....	7.60	5.84	3.66	3.0	227 to 251	226 to 250
20.....	3.46	2.60	1.56	1.7	234 to 243	234 to 241

There is less variation when the five rows are distributed throughout the plat than when adjacent; also the variation decreases as the number of repetitions increases. Evidently in the case under consideration it would be necessary to repeat about 20 times in order to obtain comparable data.

To secure more data on this point, 500 row plats of Turkey wheat were planted in the autumn of 1909. The rows were each 16 feet in length, all planted uniformly and with the same seed in soil of average fertility and in good tilth. At harvest the rows appeared to be uniform in character and would have yielded about 30 bushels to the acre. Table XIV summarizes the results.

TABLE XIV.—Yield of grain from 500 16-foot rows of Turkey wheat, systematically repeated in various ways to show experimental error.

Classification.	Number of groups.	Mean yield.	Extreme variation.	Average deviation.	Standard deviation.	Coefficient of variability.
		Grams.	Grams.	Grams.	Grams.	Per cent.
Single rows.....	500	250.7	156–403	28.67	35.85	14.34
Every 100th row, 5 rows in a group.....	a 25	242.0	219.6–277.8	13.3	15.76	6.51
	b 25	256.0	233.6–281.4	11.7	14.11	5.51
	c 25	247.3	226.4–272.6	11.9	13.03	5.27
	d 25	256.6	228.4–282.4	11.8	14.85	5.79
Average.....		250.5	227.0–278.5	12.17	14.44	5.77
Every 50th row, 10 rows in a group.....	a 25	245.1	224.1–270.7	10	12.18	4.97
	b 25	256.3	242.0–276.6	8	9.69	3.78
Average.....		250.7	233.0–273.6	9	10.93	4.37
Every 33d row, 15 rows in a group....	33	250.2	235.5–273.9	6.2	7.95	3.18
Every 25th row, 20 rows in a group....	25	250.7	234.3–269.6	7.4	9.28	3.70

In this case the experimental error was much higher than with the 100 rows of oats (Table XIII) and did not reduce so rapidly by repetition. This may be due to the fact that the 500 rows of wheat covered a greater area than the 100 rows of oats, thus having more causes for variation. It is probable that the greater the number of strains to be compared the more replications will be necessary

because of the larger area they will cover. However, when repeated 15 times, the average deviation is about half as much as when repeated 5 times, but replicating 20 times did not make a further improvement. It will be seen that the extreme variation is rather wide. It would be impossible to make a direct comparison of yield between strains or varieties tested under conditions where the variation of extremes is so large. It would be necessary in such case to select a rather large percentage of the high-yielding varieties and continue the test with them for some years. The method of selection will be hereafter explained.

WEST

671	657	703	755	760	686	592	739	732	710	753	680	680	677	795	723
202	210	211	218	218	215	215	216	217	216	212	220	221	222	223	224
658	715	613	632	667	645	660	708	786	768	666	843	795	763	716	741
123	124	125	125	127	129	129	130	131	131	130	133	134	135	137	138
687	671	623	715	543	613	640	798	759	764	995	793	926	755	792	898
177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
642	680	654	673	760	709	682	724	774	860	787	725	664	851	690	770
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166
735	580	620	675	765	742	772	698	652	661	768	777	745	768	851	719
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
575	598	705	642	704	643	650	572	752	740	863	680	722	723	703	756
129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
727	633	615	685	662	639	667	608	620	624	745	764	703	752	788	682
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
572	373	560	645	692	644	632	574	606	648	806	791	628	680	679	588
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
580	425	732	730	706	732	736	655	673	793	765	576	609	568	728	620
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
588	526	596	777	776	779	721	728	604	742	665	621	611	623	646	617
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
617	683	726	835	668	664	691	770	775	685	723	583	580	395	511	653
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
602	662	640	700	650	655	563	600	730	690	713	530	568	410	478	656
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
645	736	630	598	593	592	593	659	718	705	667	585	560	635	633	733
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
609	706	790	678	685	715	622	658	597	632	713	585	657	495	618	652
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

EAST

FIG. 10.—Diagram of plats of Turkey wheat, showing the arrangement of 224 blocks (each 5.5 feet square) and the yield of grain (in grams) for each block.

VARIATION IN YIELD FROM SMALL BLOCKS.

For this experiment 224 blocks, each 5.5 feet square, were laid out in a plat 14 blocks one way by 16 the other. The blocks were all sown to Turkey winter wheat in the fall of 1908. To sow these the drill, 5.5 feet wide, was driven straight across the first series of 14 blocks, the boundaries of the blocks being later established. Each series was sown in the same way and no path or space was allowed between the blocks. Figure 10 is a diagram of the blocks, the yield in grams being marked in each block. A large variation in yield was found in the different blocks, amounting to 100 per

cent in the extreme cases, although the appearance at harvest time was fairly uniform. These plats have been combined in various ways in order to study the yields. The results are shown in Table XV.

EFFECT OF REPETITION IN REDUCING ERROR.

The first part of Table XV shows the 224 blocks combined in various ways, namely, 56 groups of 4 blocks each when every fifty-sixth block was taken, 28 groups of 8 blocks each when every twenty-eighth block was taken, and 14 groups of 16 blocks each when every fourteenth block was taken. The 56 groups of 4 blocks each were divided into 4 sets of 14 each and the 28 groups of 8 into 2 sets of 14 each. This division into sets was for the purpose of having an equal number of blocks for comparison in each case. We find illustrations of a combination of high-yielding plats and low-yielding plats such as were noted in Table XII. For example,

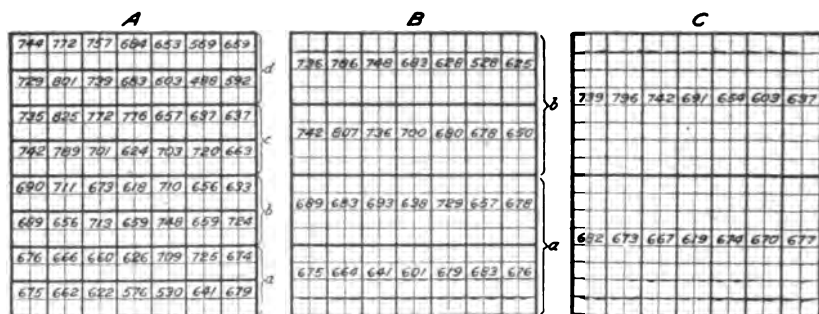


FIG. 11.—Diagrams of plats of Turkey wheat, showing the arrangement of 224 blocks (each 5.5 feet square) when combined in groups of adjacent blocks, with the average yield for each group: A, Groups of 4; B, groups of 8; C, groups of 16.

when the blocks are repeated 4 times the range in yield varies from an average of 595.2 grams per block to an average of 786.5 grams per block, a difference of 32 per cent. If varieties were being tested by the same system, this variation would be more than we might expect in the yields of different kinds.

When the blocks are repeated 8 times the average variation ranges from 627.5 to 717.8 grams, a difference of 90 grams, or 14 per cent. By repeating 16 times the extreme variation is reduced to 47 grams, or 7 per cent. However, with the exception of the extremes, the variation here is small. The question now to consider is the minimum number of blocks which will insure comparable results. If comparable results are to be secured the first season, the blocks should be repeated 15 to 20 times. If it were desirable to carry the strains for a period of 3 years, repeating 8 to 10 times would probably be sufficient, since this would give a total of 24 to 30 blocks for the 3 years.

RELATION OF SIZE OF PLAT TO VARIATION.

It is very desirable in plant-breeding work to determine the minimum size of plat that it is practicable to use, since with hundreds of strains to try each year it would be impossible to handle them in large plats. Taking the above series of 224 small blocks, the adjacent blocks could be combined to give a continuous series of larger and larger blocks. Figure 11 shows how these combinations were made and Table XV gives statistical results, showing also in a summary for two years the comparative effect of increasing the size of the block and of repeating small blocks.

TABLE XV.—Yield of Turkey wheat grown in 224 block plats (each 5.5 feet square) in 1909 and 1910.

SYSTEMATICALLY REPEATED TO FORM GROUPS OF 4, 8, AND 16 BLOCKS.

Classification.	Number in group.	Season of 1909.					Season of 1910.				
		Mean yield per block.	Extreme variations.	Average deviation.	Standard deviation.	Coefficient of variability.	Mean yield per block.	Extreme variations.	Average deviation.	Standard deviation.	Coefficient of variability.
Single blocks.	224	680.38	373-995	67.23	81.98	<i>P. ct.</i> 13	463.71	300-809	47.62	62.62	<i>P. ct.</i> 13.50
Every 56th block, 4 blocks in a group.	a	14 668.82	613.25-721.25	29.33	35.79	5.35	468.23	441.75-502.75	15.80	17.88	3.82
	b	14 689.96	645.75-786.50	32.99	39.80	5.77	467.09	412.25-504.25	15.36	21.87	4.68
	c	14 680.95	595.25-728.00	21.71	30.09	4.42	450.59	377.50-490.50	21.52	26.34	5.84
	d	14 683.36	627-744.75	24.36	32.09	4.69	468.93	403.75-581.50	35.12	44.23	9.43
Average.		680.77	620.32-745.12	27.09	34.44	5.05	463.71	413.81-515.80	21.95	27.58	5.94
Every 28th block, 8 blocks in a group.	a	14 674.20	627.50-704.88	18.04	21.63	3.21	459.41	441.38-472.50	8.46	9.65	2.10
	b	14 686.66	660.38-717.88	16.45	18.62	2.71	468.01	433.38-515.38	15.28	19.34	4.13
Average.		680.43	643.94-211.38	17.25	20.13	2.96	463.71	437.38-493.94	11.87	14.43	3.11
Every 14th block, 16 blocks in a group.		14 680.43	653.25-700.38	7.24	10.41	1.53	463.72	450.86-490.56	6.47	9.90	2.07

COMBINED IN GROUPS OF 4, 8, AND 16 ADJACENT BLOCKS, TO SHOW THE EFFECT OF SIZE OF PLAT ON VARIABILITY.

Four adjacent blocks in a group.	a	14 652	529.75-725.25	37.36	49.08	7.53	443.18	387.25-497	26.76	30.93	6.98
	b	14 681.48	617.75-748.25	30.84	35.75	5.25	465.30	389.50-576	45.62	33.86	11.57
	c	14 713.61	624.50-825	53.14	61.46	8.47	504.64	413.75-587.50	31.84	41.90	8.30
	d	14 676.78	488.25-801.50	70.96	85.80	12.67	441.71	346.75-493.25	26.37	31.49	7.13
Average.		680.97	565.06-775.00	48.07	58.02	8.48	463.71	394.31-538.44	32.65	39.34	8.49
Eight adjacent blocks in a group.	a	14 666	636.13-829	24.57	31.57	4.74	454.21	398.62-510.25	27.86	37.97	8.36
	b	14 695	586.50-706.75	55.93	70.30	10.11	473.18	894.12-545	31.55	40.01	8.45
Average.		680	611.31-767.87	40.25	50.93	7.42	463.69	396.37-527.62	29.70	38.99	8.40
Sixteen adjacent blocks in a group.		14 680	603.75-797.06	35.43	48.87	7.20	463.71	406.69-509.38	21.67	26.43	5.70

TABLE XV.—Yield of Turkey wheat grown in 224 block plats (each 5.5 feet square) in 1909 and 1910—Continued.

SUMMARY BASED ON THE AVERAGE OF BOTH SEASONS, SHOWING THE EFFECT ON COEFFICIENT OF VARIABILITY OF INCREASING THE SIZE OF PLAT AS COMPARED WITH DISTRIBUTING THE SAME AREA BY A SYSTEMATIC METHOD.

Number of blocks combined in each group.	Number of groups averaged.	Coefficient of variability.		
		Plats increased in size, blocks adjacent.	Plats distributed systematically.	Four adjacent blocks combined and combination distributed 4 times—16 blocks.
1.....	224	13.25	13.25	} 3.42
4.....	56	8.48	5.44	
8.....	28	7.91	3.03	
16.....	14	6.45	1.80	

SUMMARY BASED ON THE YIELDS OF 1909, ARRANGED TO SHOW THE RELATION BETWEEN SIZE OF PLAT AND AVERAGE DEVIATION.

Shape of plat.	Number of blocks in plat.	Total number of plats.	Average deviation.	Average deviation when plats are made up by systematic method.	
				Every—	Per cent.
1.....	1	224	Per cent. 9.76		
1 by 2.....	2	112	8.57		
1 by 4.....	4	56	7.16	} 56th block.....	5.05
2 by 2.....	4	56	7.38		
2 by 4.....	8	28	6.05	} 28th block.....	2.96
1 by 8.....	8	28	6.08		
2 by 8.....	16	14	5.30	} 14th block.....	1.53
4 by 8.....	28	8	5.37		
7 by 8.....	56	4	5.29		

Starting with a coefficient of variability of 13.25 per cent, it is decreased to 8.48 when the block is made 4 times as large, to 7.91 per cent when 8 times as large, and to 6.45 per cent when increased 16 times in size. Table XV gives the result of repeating the same number of plats equal distances apart. Here we see that where the plats are repeated 16 times the average variability for the two years rapidly decreases to 1.8 per cent.

It might appear from a study of the first part of this table that if the size of the plat were constantly increased the variability would be constantly reduced. However, increasing the size of the plat beyond a certain point does not continue to remove the cause of variability, namely, variation in soil. The last part of the table, which contains the data for 1909, is arranged to show the effect of increasing the size of the plat. It indicates a rapid decrease in variability up to plats 16 blocks in size, but no decrease in the next two cases. While acre plats are probably less variable than tenth-acre plats and tenth-acre plats less variable than hundredth-acre plats, yet plats of this size are too variable for direct comparison and they are much too large

for practical plant-breeding work. On the other hand, repeating the plats in a systematic way constantly removes the cause of variation as the number of repetitions increases. It then appears that the most practical method of removing error is to repeat series of small blocks a rather large number of times.

CONSTANCY OF VARIATION ON THE SAME PLATS.

Table XV gives statistical data for 1909 and 1910 on the same blocks arranged in the same way both years. Figure 12 shows the average yield of each section and the average percentage of nitrogen

in the two years for sections *a*, *b*, *c*, and *d*.

The yield per block varied about the same for the two years, being highest in section *c*

in both seasons. The variation in nitrogen

was not as regular, section *c* being highest in nitrogen in 1909,

while in 1910 there was a small but regular

increase in nitrogen from *d* to *a*. The second part of figure 12

shows the coefficient of variability in both yield and percentage

of nitrogen when the small blocks are combined in sets of four

(Table XV). Section *a* was highest in varia-

bility of both yield and nitrogen content in 1909 and low in 1910.

Section *b* was low in variation in yield in 1909 and high in 1910.

This would indicate that different seasons do not affect equally all parts of the plat, and illustrates the difficulty of "standardizing"

plats by the system of sowing all plats to one crop for a season in

order to determine relative yield.

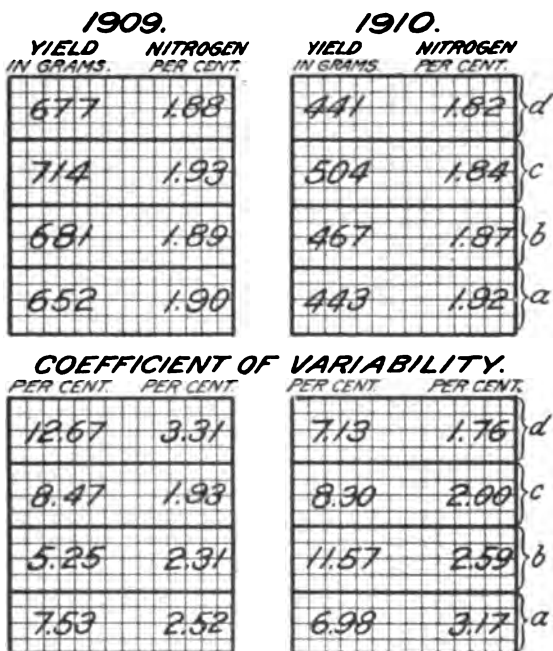


FIG. 12.—Diagrams showing Turkey wheat grown in 224 blocks, combined in four groups (Table XV, *a*, *b*, *c*, *d*) of 56 adjacent blocks to show variations in yield and nitrogen content in 1909 and 1910.

VARIATION IN YIELDS FROM CENTGENER PLATS.

The centgener method consists of planting 100 plants in a centgener, 6 inches apart each way, making blocks 5 feet square. In 1908, 178 centgener blocks were compared for variability with an equal number

of duplicate row plats 16 feet in length. The variability was found to be practically the same. Other data confirm this conclusion, although under unfavorable conditions centgener plats are quite variable, owing to the fact that the individual plants are so far apart that the missing plants are not compensated for by the tillering of neighbors, as is the case where the planting is at the normal rate.

ALTERNATING CHECK ROWS AS A MEANS OF OBTAINING COMPARATIVE YIELDS.

In order to test the value of the method of alternating check rows, the 500 rows before referred to (pp. 36-37) were used as a basis for data. It was assumed that every odd-numbered row would represent a check row, while every even-numbered row would represent a strain being compared with a check row. Thus, row No. 2 would be considered a strain to compare with rows 1 and 3 as checks. It is apparent from data heretofore presented that the error would be too great if only a single row were compared with its adjacent checks. For example, there are numerous cases in the 500-row plats where the even-numbered row would be 20 to 30 per cent higher or lower in yield than the average of the adjacent odd-numbered row plats. Table XVI shows the result of averaging five odd rows and the adjacent five even rows, i. e., rows 1, 3, 5, 7, and 9 are averaged to compare with rows 2, 4, 6, 8, and 10. In the first 10 rows, for example, the five odd rows averaged 235.6 grams per row and the five even rows 226.4 grams per row, or 9.2 grams less than their checks. In the next block the even rows yielded 9 grams more than the checks. Out of the 50 cases here cited the extremes vary from -26.6 to +32.8, with an average deviation of 10.14 grams or 4 per cent. In selective work it is the unusually high variants that are sought after, but with an experimental error greater than the expected variation they would be difficult to locate. Table XVI also shows the result of dividing the 500 rows into blocks of 20 and 40 rows and comparing the yield of odd and even rows in each case. While in most cases the average deviation is small, yet there are a number of quite wide variations. For example, when 50 series of five odd rows are compared with five even rows, 17 series, or about one-third, show a deviation greater than 5 per cent of the mean; when 25 series of 10 odd rows are compared with 10 even rows, 6 series, or about one-fourth, show greater than 5 per cent average deviation; and when 12 series of 20 odd rows are compared with 20 even rows, none show 5 per cent deviation.

EFFECT OF INCREASING LENGTH OF ROW.

To increase the length of the row will decrease the error in about the same way as to increase the size of the block. In the 500-row plats just discussed most of the rows were in series and end to end,



FIG. 1.—HEAD-TO-ROW NURSERY, IN WHICH 25 GRAINS FROM A SINGLE HEAD ARE PLANTED IN A ROW 20 INCHES LONG.

The second year the seed from each 20-inch row is planted in a 16-foot row.



FIG. 2.—ROW-PLAT NURSERY, IN WHICH THE ROWS ARE 16 FEET IN LENGTH WITH A 4-FOOT ALLEY ADJACENT, THUS MAKING THE BEDS 20 FEET IN WIDTH.

These beds are slightly rounded, to give perfect drainage.



FIG. 1.—INCREASE PLATS OF ONE-THIRTIETH ACRE EACH.
Selected strains from the nursery are tested in these plats for 3 years.



FIG. 2.—INCREASE PLATS HARVESTED AND READY TO THRASH.
The plats in this field averaged 60 bushels per acre.

with only a narrow alley a few inches in width between the ends. By adding together the rows end to end, longer rows could be made. (Pl. I.) A total of 84 rows 64 feet in length was made in this manner, and the yields calculated. Table XVI gives the variability in the original 500 rows, each 16 feet long, in comparison with the same rows when combined into lengths of 64 feet. By increasing the length four times the deviation and variability are reduced not quite one-half. The longer rows are also less variable than blocks of five adjacent 16-foot rows, but more variable than five rows distributed in a systematic way throughout the plat.

The best length of row to use must be determined by circumstances. If sufficient uniform land is available and it is more convenient to make long rows, to do so would lessen the number of repetitions of plats necessary to reduce the error within proper limits, but it would always take a larger area to secure the same degree of accuracy with the long rows.

TABLE XVI.—Yield, in grams, of Turkey wheat grown during the season of 1910 in 500 rows, each 16 feet in length.

ARRANGED BY ODD AND EVEN ROWS AND AVERAGED IN GROUPS OF TEN.¹

Rows 1 to 100.			Rows 101 to 200.			Rows 201 to 300.			Rows 301 to 400.			Rows 401 to 500.		
Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.
205	212		246	244		258	253		259	292		278	230	
226	222		235	298		233	241		317	340		278	248	
245	231		230	245		262	219		314	285		277	280	
262	238		243	226		182	220		223	219		307	300	
240	229		266	231		246	239		238	262		283	295	
235.6	226.4	- 9.2	245	244.8	3.8	236.2	234.4	- 1.8	270.2	279.6	9.4	284.6	278.6	- 6
140	183		228	226		224	218		198	223		268	250	
214	255		242	266		222	261		251	287		258	250	
256	220		220	227		256	234		223	204		253	250	
216	234		213	235		229	241		209	223		242	239	
237	256		225	245		292	198		229	194		189	247	
220.6	229.6	9	225.6	239.8	14.2	244.6	230.4	-14.2	222	226.2	4.2	242	255.2	13.2
214	231		271	212		235	229		216	216		244	276	
235	208		235	238		235	271		222	204		200	217	
244	316		247	227		235	212		245	236		316	285	
275	240		247	255		221	242		231	194		194	243	
272	228		267	296		273	269		200	218		363	343	
256	244.6	-11.4	253.4	245.6	- 7.8	239.8	244.6	4.8	222.8	213.6	- 9.2	271.4	272.8	1.4
272	239		269	259		219	255		228	200		248	294	
275	215		250	289		270	240		227	228		340	338	
224	237		278	246		275	191		218	208		326	287	
220	240		222	256		282	249		242	257		265	315	
182	263		308	276		268	237		221	230		314	290	
234.6	238.8	4.2	265.4	265.2	- .2	262.8	242.4	-20.4	227.2	224.6	- 2.6	306.6	304.8	- 1.8
156	252		297	280		213	246		215	252		328	273	
227	263		230	310		255	269		269	210		324	315	
254	224		323	263		235	242		171	228		300	279	
226	188		317	261		247	268		230	207		252	249	
246	255		305	268		303	242		222	200		331	273	
221.8	236.4	14.6	294.4	276.4	-18	250.6	253.4	2.8	221.4	219.4	- 2	307	277.8	-29.2

¹ Average difference in yield between odd and even rows, grams, 10.4; per cent, 4.

TABLE XVI.—Yield, in grams, of Turkey wheat grown during the season of 1910 in 500 rows, each 16 feet in length—Continued.

ARRANGED BY ODD AND EVEN ROWS AND AVERAGED IN GROUPS OF TEN—Continued.

Rows 1 to 100.			Rows 101 to 200.			Rows 201 to 300.			Rows 301 to 400.			Rows 401 to 500.		
Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.
227	247		275	249		257	225		282	246		224	303	
230	285		241	269		190	204		269	240		349	320	
263	281		285	245		227	250		250	230		272	283	
255	255		249	222		222	174		233	268		291	331	
280	280		246	223		209	216		213	200		308	271	
251	269.6	18.6	259.2	241.6	-17.6	220.8	213.8	-7	249.4	236.8	-12.6	268.8	301.6	32.8
275	237		232	228		229	187		200	207		269	293	
264	277		200	228		200	215		219	233		293	327	
268	227		262	242		238	238		225	207		257	263	
204	213		227	239		242	202		205	230		254	244	
237	202		246	222		190	245		243	216		250	311	
249.6	232.2	-17.4	237.4	231.8	-5.6	223.8	217.4	-6.4	218.4	218.6	.2	264.6	287.6	23
235	229		266	267		218	212		250	208		286	243	
204	210		351	312		212	184		276	254		297	403	
257	312		265	300		234	267		235	245		316	285	
294	295		322	313		211	213		243	255		297	239	
313	315		293	285		232	284		257	281		211	247	
260.6	272.2	11.6	299.4	299.4	0	221.4	232	10.6	252.2	248.6	-3.6	281.4	283.4	2
233	265		248	273		230	219		298	316		208	219	
276	214		233	243		236	228		261	208		255	255	
327	300		290	261		290	314		225	248		243	269	
312	316		259	263		208	195		233	226		247	275	
370	290		248	272		225	219		205	214		249	266	
303.6	277	-26.6	253.6	262.4	8.8	237.8	235	-2.8	244.4	242.4	2	240.4	260.8	20.4
271	236		241	250		232	211		250	230		217	215	
251	246		266	254		185	257		254	211		235	285	
269	251		310	263		242	242		305	269		252	235	
217	242		245	245		279	270		237	216		222	289	
298	308		275	269		265	270		242	192		271	288	
261.2	256.6	-4.6	267.4	256.2	-11.2	240.6	250	9.4	237.6	223.6	-14	239.4	262.4	23

SUMMARY OF ODD AND EVEN ROWS ARRANGED IN BLOCKS OF 20 AND 40 ROWS TO SHOW DEVIATION.

The 10 odd and 10 even rows from each adjacent 20 grouped together.						The 20 odd and 20 even rows from each adjacent 40 grouped together.		
Odd.	Even.	Difference.	Odd.	Even.	Difference.	Odd.	Even.	Difference.
229.1	228.0	-0.1	222.6	224.7	+2.1	236.7	234.8	-1.9
245.3	241.7	-3.6	239.2	242.5	+3.3	245.7	252.6	+6.9
236.4	253.0	+16.6	246.1	252.9	+6.8	258.8	255.5	-3.3
255.1	252.2	-2.9	225.0	219.1	-5.9	268.1	257.2	-10.9
282.4	266.8	-15.6	235.4	228.1	-7.3	264.4	263.9	0.5
235.3	244.3	+9.0	235.3	233.6	-1.7	245.8	237.9	-7.9
259.4	255.4	-4.0	241.0	233.0	-8.0	229.1	229.1	0
276.8	259.0	-17.8	263.3	266.9	+3.6	242.6	247.7	+5.1
268.4	268.6	+0.2	271.0	288.8	+17.8	230.2	223.6	-6.6
260.5	259.3	-1.2	287.9	289.7	+1.8	238.1	233.3	-4.8
240.4	232.4	-8.0	273.0	285.5	+12.5	267.1	277.8	+10.7
251.3	243.5	-7.8	239.9	261.6	+21.7	280.4	287.6	+7.2
235.7	233.6	-2.1						
Average difference.					7.256	Average difference.		5.483

SUMMARY SHOWING RESULT OF COMBINING 16-FOOT ROWS IN VARIOUS WAYS.

Classification.	Extreme variation.	Standard deviation.	Coefficient of variability.	Classification.	Extreme variation.	Standard deviation.	Coefficient of variability.
500 single rows 16 feet long.....	156-403	35.85	Per cent. 14.33	5 adjacent rows 16 feet long.....	212-317	26.11	Per cent. 10.38
84 rows 64 feet long (4 times length of above).....	196-284	21.43	8.8	5 rows 16 feet long distributed (every 100 rows).....	227-278	14.44	5.77

Table XVII shows a comparative summary, based on the data herein reviewed, from which it appears that to repeat the 5.5-foot square blocks, in series, will reduce the error at the greatest rate, while to repeat the 16-foot rows will give the next most rapid reduction. However, the method of alternating 5 odd rows with 5 even rows gave about as good results as to repeat 10 rows, and the system of alternate planting with check rows would sometimes be desirable.

TABLE XVII.—*Summary showing coefficients of variability under various systems of arranging block plats and row plats.*

Kind of plats and arrangement.	Number of plats combined.					Remarks.
	1	5	10	15	20	
Blocks 5.5 feet square (Table XV):						
Adjacent.....	13	8	7	6.4	.....	Variation will not continue to decrease.
Repeated.....	13	5	2.5	1.8	.....	Variation decreases to infinity.
Rows 16 feet long (Table XVI):						
Adjacent.....	14	11	7	5	3.5	Variation does not continue to decrease.
Repeated.....	14	5	4	3.2	3.7	Variation decreases to infinity.
Alternated.....	14	.....	4	3.6	3	Do.

To correct by check plats is sometimes uncertain, as pointed out hereafter, and therefore the advantage seems to be with the method of systematic repetition of rows or blocks. The repetition of the square blocks 10 times gave a higher degree of accuracy than repeating rows even 15 and 20 times, and it seems probable that further experimenting is likely to show the block system to be the most accurate for close comparisons. It also does away with the competition which no doubt takes place between adjacent rows, and also makes note taking easier by giving a mass effect, such as is secured under field conditions. To increase the size of plat will also reduce error, as shown by Table XV, and on the basis of these data a plat, about three times the size of the 5.5-foot blocks reported on, is being tested. This block is 4.2 by 16 feet in size, and indications are that with this block the variation will be reduced about one-half, as compared with the 5.5-foot block.

INFLUENCE OF RATE OF PLANTING ON YIELD.

For several years in planting our row plats care was taken to plant the same number of seeds in each row. In case of wheat, 400 kernels usually were planted to the 16-foot row, which was equivalent to the normal rate of seeding, or 5 pecks per acre. However, in 1908 and 1909 counts of the number of plants harvested were made of many rows at harvest time. In the row plats of wheat where the rate of seeding was about normal it was found that only about 60 to 80 plants

were harvested to every 100 kernels planted. A variation of 20 per cent in stand was not apparent to the observer because all plats would appear to have an equally good stand at harvest time. This loss of plants was due to many causes, such as winterkilling, insects, and accidents, but chief among the causes appeared to be the normal competition of plants. For example, certain plants were weak or were slow in starting spring growth; the stronger plants would quickly outdistance them, causing at least a certain percentage of the weaker plants to perish as a result of competition. It seemed doubtful, however, whether this difference in plants harvested had a marked effect on yield. For example, here and at many experiment stations tests have been made with sowing wheat at various rates, from 4 pecks to 10 pecks per acre. The difference in yield is never large. Doubling the amount of seed sown, from 4 to 8 pecks per acre, does not double the yield, and in many cases does not affect it at all. This is due to the tillering power of the plant, which is able in this way to compensate for the difference in number of plants.

To make a test of the rate of planting under row-plat conditions, a series of plats was planted with Red Rustproof oats in the spring of 1910. Each row plat was 16 feet in length. There were 5 plats in the series, planted at the rate of 400, 500, 600, 700, and 800 grains per plat. The series was repeated 20 times, making 100 rows in all. The results are shown in Table XVIII.

TABLE XVIII.—Results of rate-of-seeding test on 100 16-foot rows of Red Rustproof oats.

Statement of averages.	Number of grains sown per row.				
	400	500	600	700	800
Number of plats averaged.....	20	20	20	19	20
Average yield per row.....grams.....	197	213	215	215	234

The normal rate of seeding would have been about 600 grains per row. It appears from the data that a slight variation in rate of planting, as 25 or 50 grains more or less than normal, would not affect the results.

To further test the effect of rate of seeding, a series of 60 blocks was laid out, each block being 5 drill rows wide and 16 feet in length. As the drill rows were 10 inches apart, this made the plats each 4.2 by 16 feet. The blocks were planted with a small drill devised for the purpose. Five rates of seeding were used, namely, 42.6, 49.1, 55.9, 65.4, and 73.3 grams per block. The series was repeated 12 times, giving 12 blocks of each rate for averaging. The results are shown in Table XIX.

TABLE XIX.—Results of rate-of-seeding test on 60 block plats of Kherson oats.

Statement of averages.	Weight of seed sown (grams).				
	42.6	49.1	55.9	65.4	73.3
Number of blocks averaged.....	12	12	12	12	12
Average yield per block.....grams	1,069	1,101	1,151	1,149	1,156

The normal rate of seeding would be about 60 grams per block, and it is apparent from the data that a variation of 10 or even 20 per cent above or below normal in the weight of seed used would not have a marked effect on the yield.

In view of the data just presented, it would seem not to be necessary to actually count the number of seeds to be planted in each small plat, providing some other quicker means can be found of obtaining approximate accuracy. If the seed is first carefully fanned, scoured, and screened to one size, equal volumes will usually not vary more than a small percentage in number of kernels. Also equal weights will have approximately the same number of kernels, provided the seed has first been carefully prepared by fanning and screening to a uniform size.

EFFECT OF COMPETITION BETWEEN ADJACENT ROWS.

In 1908 it was observed that a certain strain of early wheat in a series of row plats made a very poor appearance at harvest time, while the same strain planted in centgeners made a much better comparative showing. Apparently the larger and faster growing strains on each side, the rows being only 8 inches apart, exercised some competitive effect. This effect of competition has been noted for two years since. Also in certain variety tests of oats, grown in row plats 10 inches apart, the same effect was noted. Exact data can not be given on this point, as the results from the series of plats planted in 1909 and in 1910 for this purpose were seriously impaired by unfavorable conditions; but Table XVIII, giving results from adjacent row plats sown at different rates, shows that the 800-seed rate made a marked increase over the 700-seed rate, while in a similar series of blocks (Table XIX), sown at the same rate, this marked increase was not noted. Since the 800-seed row was always adjacent to the 400-seed row, it may have had some advantage on this account. Danger from this source can probably be avoided if care is taken to plant only similar varieties in adjacent rows. Where the block plat is used this source of error is eliminated.

VARIATION IN PURE STRAINS AND RELATION OF DATA IN CENTGENER NURSERY AND IN FIELD PLATS

ISOLATION OF PURE STRAINS.

In 1902, Dr. T. L. Lyon, now of Cornell University, planted 800 heads of Turkey winter wheat in a centgener nursery, arranging to keep a record of the progeny of each head. The heads were numbered from 1 to 800 and these original numbers are still retained as family numbers. The original plan was to select for increased nitrogen content and yield, discarding those families which did not show high averages in both these respects, and to practice continuous selection of individual plants from among those families that were promising. A considerable number of the families were discarded each year, until at the end of harvest in 1906 only 47 of the original 800 were retained for further work. At this time the writer took up the work and the practice of continuous selection was discontinued as it began to be apparent that the isolation of pure strains was a more promising way of obtaining results. The 47 pure strains were put in field plats to test for yield. Complete records, however, can be given on only 24 pure strains, as all but 26 were dropped in 1908 for lack of space, and the nursery data are incomplete on 2 strains out of the 26. These strains are shown in field plats in Plate II. Table XX gives the average results for four years, both in the centgener nursery and in the field plats. By "centgener" is meant the method of planting 100 seeds from a single plant in a square plat, the plants 6 inches apart each way.

TABLE XX.—*Relations of certain characters of 24 strains of Turkey wheat grown in nursery and in field and tested during 4-year periods.*

RANKED IN GROUPS OF FIVE IN ORDER OF YIELD IN THE FIELD.

Data from centgener nursery (average for four years, 1906-1909).								Data from field plats (average for four years, 1907-1910). ¹		
Family No. (The numbers in <i>italic</i> indicate the five highest yielders.)	Nitrogen content.	Yield per—		Average weight of kernels, 1903-1906.	Strength of straw.	Fruiting period.	Number of centgen-ers averaged.	Nitrogen content.	Yield.	Number of plats averaged.
		Plant.	Centgener, 1906-1908.							
	<i>P. ct.</i>	<i>Grams.</i>	<i>Gms.</i>	<i>Grams.</i>	<i>P. ct.</i>	<i>Days.</i>		<i>P. ct.</i>	<i>Bush.</i>	
48.....	2.66	13.38	764	0.02192	80	36	22	2.60	40.75	9
287.....	2.52	12.38	704	.01864	81	35	23	2.49	40.59	12
42.....	2.68	11.58	622	.02105	63	35	23	2.48	39.90	5
312.....	2.61	12.27	646	.02344	68	36	31	2.55	39.21	9
425.....	2.70	9.83	612	.01824	67	35	35	2.56	39.18	8
Total or average.....	2.63	11.89	670	.02058	72	35	134	2.54	39.93	43
556.....	2.72	12.36	593	.02267	55	36	38	2.54	38.86	5
223.....	2.53	11.12	623	.01984	65	35	29	2.55	38.78	10
215.....	2.63	11.14	605	.02064	70	34	48	2.54	38.64	8
47.....	2.60	12.26	664	.02013	63	36	123	2.51	38.50	39
3.....	2.70	11.01	620	.02168	63	34	18	2.53	38.48	23
Total or average.....	2.64	11.58	621	.02099	63	35	256	2.53	38.65	85

¹ Averages of check plats: Nitrogen content, 2.61 per cent; yield, 35.18 bushels.

TABLE XX.—Relations of certain characters of 24 strains of Turkey wheat grown in nursery and in field and tested during 4-year periods—Continued.

RANKED IN GROUPS OF FIVE IN ORDER OF YIELD IN THE FIELD—Continued.

Family No. (The numbers in <i>italics</i> indicate the five highest yielders.)	Data from centgenet nursery (average for four years, 1906-1909).							Data from field plots (average for four years, 1907-1910).		
	Nitrogen content.	Yield per—		Average weight of kernels, 1903-1906.	Strength of straw.	Fruiting period.	Number of centgenet-ers averaged.	Nitrogen content.	Yield.	Number of plots averaged.
		Plant.	Centgenet, 1906-1908.							
391.....	P. ct. 2.70	Grams. 10.93	Gms. 510	.02185	64	34	28	2.51	37.96	5
221.....	2.63	12.46	647	.02205	64	34	59	2.59	36.57	12
313.....	2.50	11.95	597	.02118	68	36	114	2.53	36.27	5
379.....	2.81	11.05	563	.02016	60	34	20	2.70	36.13	5
386.....	2.59	11.06	558	.01889	65	34	26	2.58	36.12	5
Total or average.....	2.65	11.49	575	.02111	64	34	247	2.58	36.61	32
314.....	2.68	9.70	560	.02020	66	34	52	2.63	35.22	8
168.....	2.63	10.70	512	.02247	63	34	23	2.60	34.84	5
526.....	2.76	10.03	614	.02029	66	34	18	2.73	34.20	8
379.....	2.84	10.79	620	.02057	62	34	20	2.71	33.56	5
216.....	2.52	12.11	594	.02108	66	35	43	2.48	33.46	5
Total or average.....	2.69	10.67	580	.02089	65	34	156	2.63	34.26	34
399.....	2.49	11.38	570	.01915	82	34	37	2.45	32.93	8
37.....	2.87	11.27	526	.02270	54	34	48	2.75	32.58	5
2.....	2.56	9.86	548	.02180	58	36	33	2.55	31.88	8
328.....	2.62	11.89	508	.02522	62	33	30	2.73	28.88	5
Total or average.....	2.63	11.10	538	.02228	64	34	148	2.62	31.56	26

SUMMARY OF RESULTS, ARRANGED IN GROUPS OF FIVE STRAINS AND RANKED IN VARIOUS WAYS.

CENTOGENET TESTS.										
In order of nitrogen content:										
37, 379, 377, 526, 556.....	2.80	11.10	583	.02128	59	34	144	2.69	35.07	25
425, 391, 3, 314, 42.....	2.69	10.61	585	.02060	65	34	156	2.64	38.15	49
48, 221, 168, 215, 328.....	2.63	11.91	607	.02224	68	34	182	2.51	35.94	42
512, 47, 206, 2, 225.....	2.58	11.32	608	.02082	64	35	242	2.55	36.90	71
287, 216, 313, 209.....	2.51	11.95	616	.02001	74	35	217	2.49	35.81	33
In order of strength of straw:										
209, 387, 48, 215, 312.....	2.58	12.11	658	.02076	76	35	161	2.53	38.42	46
313, 425, 314, 526, 216.....	2.63	10.72	595	.02020	67	35	262	2.59	35.67	34
206, 225, 391, 221, 3.....	2.63	11.32	592	.02104	64	34	160	2.55	37.58	55
42, 168, 47, 379, 328.....	2.67	11.44	585	.02189	63	34	219	2.61	35.14	62
377, 2, 556, 37.....	2.74	11.13	558	.02183	57	35	139	2.63	34.86	23
In order of yield per plant:										
48, 221, 387, 556, 312.....	2.63	12.57	671	.02192	70	35	173	2.55	39.20	47
47, 216, 313, 328, 42.....	2.58	11.96	597	.02173	64	35	333	2.55	35.40	62
209, 37, 215, 225, 206.....	2.62	11.20	576	.02024	67	34	188	2.57	35.81	36
377, 526, 3, 391, 379.....	2.76	10.76	585	.02091	63	34	104	2.64	36.07	43
168, 2, 425, 314.....	2.64	10.02	558	.02068	63	35	143	2.58	35.28	32
In order of yield per centgenet:										
48, 387, 47, 221, 312.....	2.60	12.55	685	.02041	71	35	258	2.55	39.12	81
225, 42, 3, 379, 526.....	2.70	10.91	620	.02068	64	34	108	2.60	36.98	48
425, 215, 313, 216, 556.....	2.61	11.48	600	.02076	65	35	278	2.53	37.28	34
209, 377, 314, 206, 2.....	2.63	10.61	560	.02040	66	34	168	2.58	34.46	34
377, 168, 391, 328.....	2.70	11.20	514	.02306	61	34	129	2.65	33.56	23
FIELD-FLAT TESTS.										
In order of nitrogen content:										
37, 526, 328, 379, 377.....	2.78	11.01	566	.02179	61	34	136	2.72	33.07	25
314, 48, 168, 221, 206.....	2.64	11.46	608	.02129	68	34	182	2.60	36.70	42
425, 2, 225, 312, 556.....	2.62	11.09	604	.02120	63	36	166	2.55	37.58	40
215, 3, 313, 391, 47.....	2.63	11.46	604	.02120	66	35	331	2.52	37.97	80
287, 42, 216, 209.....	2.55	11.86	622	.01998	73	35	126	2.47	36.72	33
In order of yield per acre:										
48, 387, 42, 312, 425.....	2.63	11.89	670	.02058	72	35	134	2.54	39.93	43
556, 225, 215, 47, 3.....	2.64	11.58	621	.02099	63	35	256	2.53	38.65	85
391, 221, 313, 377, 206.....	2.65	11.49	575	.02111	64	34	247	2.58	36.61	32
314, 168, 526, 379, 216.....	2.69	10.67	580	.02089	65	34	156	2.63	34.26	34
209, 37, 2, 328.....	2.63	11.10	538	.02228	64	34	148	2.62	31.56	26

To sum up, the 24 pure strains have varied in the centgeners from 2.49 to 2.87 in per cent of nitrogen, from 54 to 82 per cent in strength of straw, from 9.70 to 13.38 grams in yield per plant, and from 508 to 764 grams in yield per centgener. They also have shown a variation



FIG. 13.—Field plats of pure strains and check plats of original seed of Turkey wheat, 1910. The upper numerals are family numbers; the lower, 4-year average yields. Two of the poorest yielders out of 26 strains came adjacent to two of the best. The difference in yield would not have been suspected from the appearance of the plats.



FIG. 14.—Wheat nursery plats, showing variations in winterkilling. Pure strains were alternated with the original Turkey wheat from which the strains were isolated. The original was mostly winterkilled while many of the select strains withstood the winter well.

in average weight of kernel ranging from 0.01824 to 0.02522 gram. In the field plats the percentage of nitrogen varied from 2.45 to 2.75 and the yield per acre from 28.8 to 40.7 bushels—a difference of about 12

bushels. Some of these plats and the check plats noted below are shown in figure 13. It is interesting to note that the check plats of original unselected Turkey winter wheat averaged 35.18 bushels per acre, or about halfway between the highest and lowest pure strains. More strains surpass the check in yield than fall below it, but this is probably because a large percentage of the poor-yielding strains were discarded after the first field test in 1907. It appears that neither the original selection of the 800 heads, nor the discarding of centgeners in the nursery, nor the continuous selection of high-yielding plants within the centgeners had any effect on eliminating the poor yielders. There was a marked difference in the appearance of the pure strains, some



FIG. 15.—Field plats, showing variations in winterkilling between two pure strains of Turkey wheat. Strain No. 377 is shown at the right and No. 102 at the left; No. 377 withstood the winter almost perfectly.

having short grains and others long grains. They also varied in color, lodging, and general appearance in the field, both in fall growth and spring growth. Figures 14, 15, 16, and 17 illustrate these variations better than they can be described.

Table XX also shows the data from Table XV grouped in series of 5, and arranged in various ways to illustrate relationships. The principal considerations in this work were the improvement of wheat in nitrogen and yield. Records were kept of many characters of the plant in the nursery, but evidence points to six that are of interest, namely, (1) nitrogen content, (2) yield per plant, (3) yield per cent-gener, (4) weight of kernel, (5) strength of straw, and (6) length of fruiting period.

PERCENTAGE OF NITROGEN.

The percentage of nitrogen is in inverse ratio to strength of straw and length of fruiting period, but has no direct relation to other characters. It is transmitted in the field plats as indicated in the summary of Table XX. A striking example of this conclusion is seen in a comparison of families Nos. 209 and 37, Table XX. These families represent the two extremes in percentage of nitrogen and strength of straw, with an inverse relation, but are nearly the same in all other characters.

From 1903 to 1906, records were kept of individual plants selected from the nursery. When these plants were classified according to



FIG. 16.—Increase rows of Turkey wheat, showing variations in the time of heading in different strains, each from a single plant. Four rows of each strain are grown.

percentage of nitrogen or size of kernel, regardless of the family from which they came, there was a marked inverse relation, the percentage of nitrogen increasing as the size of kernel decreased. It seems probable, however, that the individual plants having small kernels may have suffered some degree of arrested development, since this relation disappears when the pure strains are so classified. Percentage of nitrogen and yield per acre in field plats vary inversely.

STRENGTH OF STRAW.

Strength of straw varies inversely with percentage of nitrogen and directly with yield per acre and yield per centgener.



FIG. 1.—TYPE OF ROAD GRADER OR DRAG USED IN GRADING A NURSERY INTO BEDS 20 FEET WIDE TO AFFORD UNIFORM DRAINAGE.

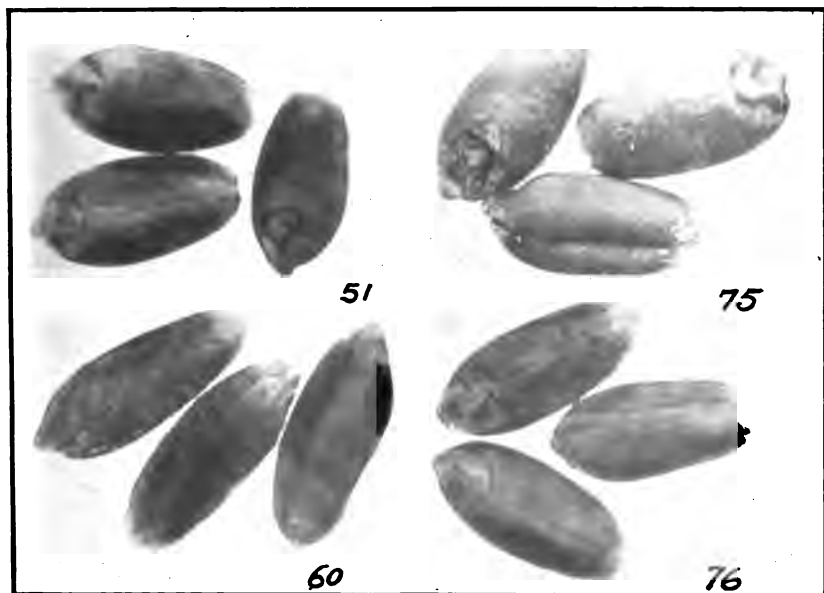


FIG. 2.—GRAINS OF TURKEY WHEAT, SHOWING VARIATION IN APPEARANCE.

Nos. 51 and 60 are typical kernels from two pure strains and represent the shortest and longestkerneled types out of 80 strains. No. 76 is a hard, vitreous kernel, somewhat approaching the durum wheat in type. No. 75 is a soft wheat. The plants of this strain are typical Turkey in appearance but the grain is larger and almost white. Notwithstanding the white color, this strain was the highest in nitrogen content of 80 strains in 1910.

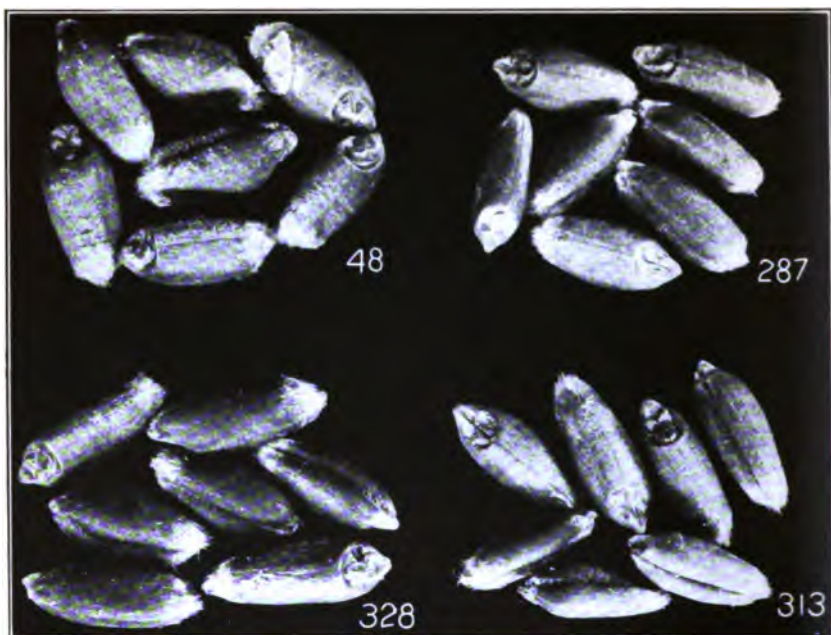


FIG. 1.—REPRESENTATIVE KERNELS FROM 4 STRAINS OF TURKEY WHEAT, SELECTED TO SHOW VARIATION IN APPEARANCE.

No. 48 is a large plump-kernelled strain, while No. 287 has a rather small kernel. No. 328 has a large dark-colored kernel, while No. 313 has a decided yellow color and is long and pointed.

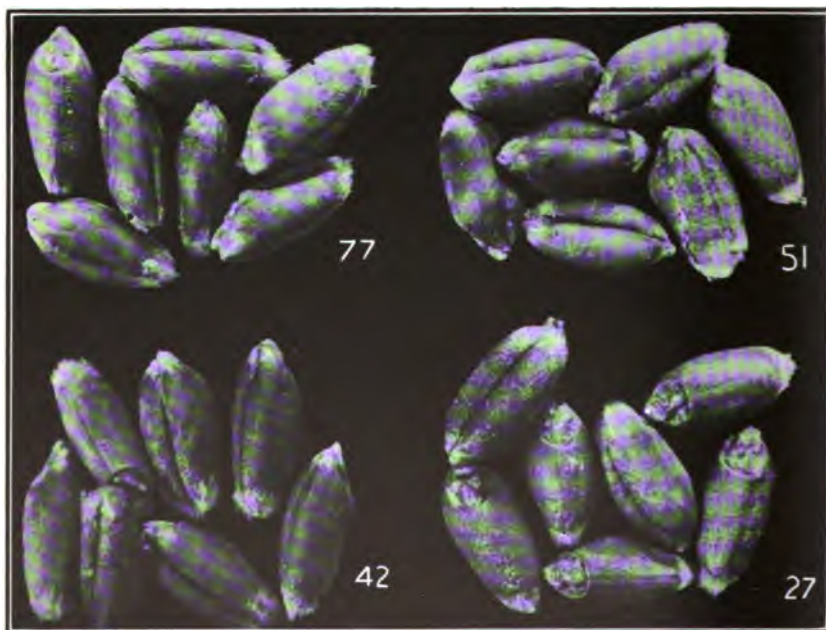


FIG. 2.—REPRESENTATIVE KERNELS FROM 4 STRAINS OF TURKEY WHEAT, SELECTED FROM A SERIES OF 80 STRAINS TO SHOW VARIATION IN QUALITY.

On the basis of a perfect wheat, grading 100, these strains grade as follows: No. 77 grades 50, No. 51 grades 70, No. 27 grades 80, and No. 42 grades 95.

YIELD PER PLANT.

The yield per plant shows some correlation to yield per acre and yield per centgener, but this correlation is not high, as it is only in the first class that the correlation is marked. One of the best-yielding strains (No. 425) had a small plant yield in the nursery.

YIELD PER CENTGENER.

The yield per centgener shows a high correlation with yield per acre and strength of straw, but not a close relation to other characters.

SIZE OF KERNEL.

The size of kernel (Pl. III, fig. 2) appears to have no fixed relationships; as a character of a pure strain it seems to be independent of other characters. An example of this is shown in Table XX. Families



FIG. 17.—Field plats of Turkey wheat, showing variations in stiffness of straw in two strains. Each strain originated from a single plant.

Nos. 287 (Pl. IV, fig. 1) and 425 have small kernels, but they are among the best in yield, while No. 328 (Pl. IV, fig. 1) is poorest in yield, but has the largest kernel. Nos. 48 and 287 are the best yielders out of the 26 strains (Table XX), averaging 40.7 and 40.6 bushels per acre, respectively, in a four-year test. No. 48 has a large, plump kernel, while No. 287 has a rather small kernel. No. 328 has averaged 28.9 bushels under the same conditions, yet this strain has a large, dark-colored kernel. Our records do not seem to show a relation between the appearance of the berry and the yield. No. 313 has averaged 36.3 bushels per acre, but the kernel has a decided yellow color, and is long and pointed in shape, approaching a rye grain in type.

QUALITY OF KERNEL.

As already noted, there does not seem to be a definite relation between the appearance of the berry and the yield of the strains.

Plate IV, figure 2, illustrates four strains of Turkey wheat selected from a series of eight strains to show variation in quality. On the basis of a perfect wheat grading 100 these strains grade as follows: No. 77 grades 50, No. 51 grades 70, No. 27 grades 80, and No. 42 grades 95. These grades indicate the variation in quality found in pure strains and show the great possibility of improving quality (fig. 18).

To sum up, high yield in the field is associated with high yield per centner and strong straw, has a slight relation to size of plant, no relation to size of berry, and varies inversely with percentage of



FIG. 18.—Cereal laboratory, showing the method of taking notes on quality. Comparisons of 80 strains of Turkey wheat are being made. There were 10 plats of each strain, making 800 in all, but the 10 samples of each strain are arranged together. Notes are taken on each sample separately, then an average is made of the results. To facilitate note taking, a set of "standard samples" representing different qualities is kept in long, 2-ounce vials. A set of these vials is plunged into the sample, and by comparison very accurate data are obtained.

nitrogen. A high or a low nitrogen content as indicated in the nursery gives correlated results in the field. High nitrogen content is antagonistic to high yield. However, an occasional strain, such as No. 48, combines a fair percentage of nitrogen with high yield.

SUPERIORITY OF STRAIN.

From the point of view of yield per acre there would seem to be little choice among the five best strains (Table XX), but in some ways No. 48 is outstanding in desirable qualities. With a high yield

per acre, it still is above the average in nitrogen content, has a strong straw and a large berry of good appearance. It is also very winter resistant, as was shown in the severe winter of 1909-10, when it came through with much less winterkilling than standard varieties, such as Big Frame and ordinary Turkey wheat.

COMPARISON OF ROWS, CENTGENERS, BLOCKS, AND FIELD PLATS.

In 1909-10 the 26 strains of Turkey wheat were sown in field plats and duplicated in rows, centgeners, and blocks, but this portion of the nursery was winterkilled. However, very good results were obtained with 11 varieties of oats sown in the spring of 1910 in all four ways. The field plats were one-fifteenth of an acre in size and



FIG. 19.—Block nursery, showing blocks 4.2 by 16 feet in size. The beds are slightly elevated, as in the row nursery.

were repeated three times. Each variety was repeated 10 times in centgeners, rows, and blocks. The centgeners were each 5 feet square and contained 100 plants 6 inches apart each way. The rows were 12 feet in length and the grain sown in them at the rate of 10 pecks per acre, the usual rate of seeding in this region. The blocks were each 4.2 by 16 feet, or 5 drill rows wide (fig. 19), and sown at the usual rate of seeding. The results summarized in Table XXI show a high degree of correlation between the yield of the field plats and the rows and blocks, but practically no correlation in the case of centgeners. Except for the Lincoln oat, which yielded exceptionally high in the nursery, the correlation in the rows and blocks would be very high.

TABLE XXI.—*Yields of grain from 11 varieties of oats grown in field plats, centgeners, rows, and blocks.*

[The field plats were repeated 3 times, the others 10 times.]

Variety.	Average yield of thrashed grain.			
	Field plats, per acre.	Centgeners.	Rows.	Blocks.
	<i>Bushels.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Burt.....	60.7	729.2	238.2	1,196.8
Texas Red.....	60.6	622.9	206.9	1,047.2
Average.....	60.65	676.05	222.55	1,122.0
Swedish Select (01).....	55.8	584.3	213.5	865.8
University No. 6.....	55.3	572.8	178.0	867.1
No. 855.....	55.2	473.7	167.0	809.8
Average.....	54.77	543.6	186.16	847.56
American Banner.....	51.9	550.9	170.4	800.8
Lincoln.....	51.8	654.4	207.3	1,071.5
No. 1174.....	51.0	601.3	184.2	842.5
Average.....	51.56	602.2	187.3	904.93
Average without the Lincoln oat.....		576.1	177.3	821.6
Swedish Select (09).....	50.3	560.4	170.8	791.1
No. 611.....	49.8	581.1	174.3	760.4
No. 70.....	49.3	470.3	159.6	776.7
Average.....	49.83	537.26	168.23	776.26

It is possible that the lack of correlation with the centgeners in the last three groups is due to the fact that the lower yielding ones were rather late, coarse-strawed, and rank-growing strains. Under the thin planting of the centgeners every plant had opportunity to develop to full size, which probably gave a slight advantage to the later and coarser types, which was not apparent under the usual rate of seeding. Table XX, giving results for 24 strains of Turkey wheat, shows a perfect correlation between yield of centgener and field plats, wherein the wheat strains were all similar, there being no great difference in time of maturity or habit of growth. This suggests that when similar strains are being compared data on the average yield of centgeners would be reliable, but that in the case of dissimilar varieties, especially of large ones and small ones, the results would not be comparable with those obtained under field conditions.

COST OF PLANTING AND HARVESTING CENTGENERS, ROWS, AND BLOCKS.

When a large number of strains is being tested in rows or blocks and the series is repeated ten to twenty times, the question of time and relative cost becomes one of importance. Rapidity of planting and harvesting is probably the matter of first consideration, as it is desirable to have these operations performed in the shortest possible time in order to secure comparable conditions.

Table XXII is a summary showing the relative number of plats of each kind that can be planted in a day by one gang of men, based on our experience. All preliminary work, such as preparing the land, sorting and labeling the seed, preparing stakes, etc., is done beforehand. However, there is usually time for preliminary work, so that

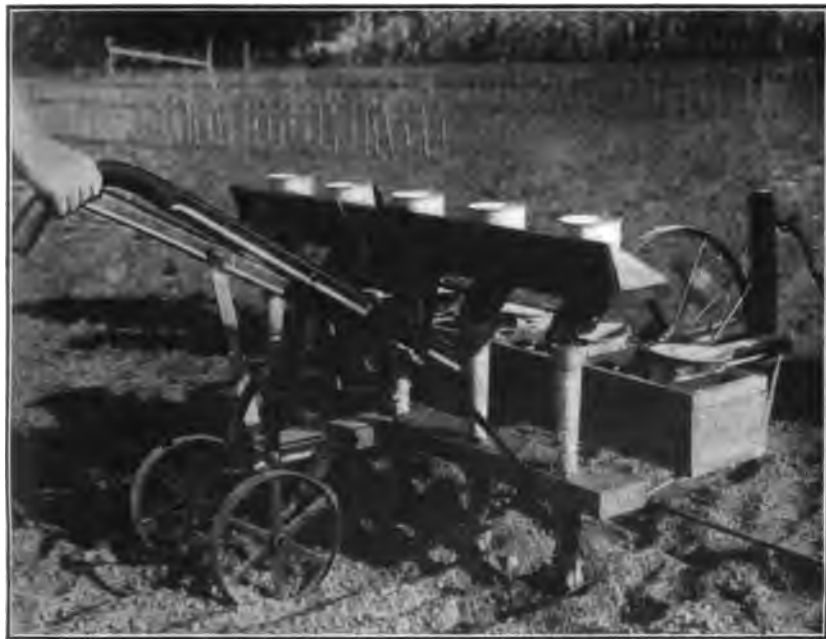


FIG. 20.—Five-row nursery drill used for planting row plats and block plats. Four or five men with this drill will easily plant 500 row plats in a day, where not more than 100 row plats could be planted by hand. The work of the drill is also more uniform and satisfactory than planting by hand.

the method of planting that permits the greatest rapidity has some advantage. The planting is done with a nursery drill (fig. 20), the harvesting with hand sickles (fig. 21), and the thrashing with a small power machine.

TABLE XXII.—Comparative number of plats of different types that can be planted or harvested in 10 hours.

Kind of plat.	Men in gang.	Number of plats covered in 10 hours.		
		Planted.	Harvested.	Thrashed, weighed, etc.
Centgener, using centgener planter.....	5	100	250	500
16-foot row plat, row made with hoe or spade and planted by hand.....	5	100	500	750
16-foot row plat, planted with nursery row drill.....	5	500	500	750
Block 4.2 by 16 feet, planted with nursery row drill.....	5	150	200	250

USE OF CHECK PLATS.

In nursery work where plats are repeated 10 or more times the checks will not be needed as a means of correcting error. Their principal use here is to determine the degree of experimental error. For example, in 1910 we had in one series 80 strains of Turkey wheat. The series was repeated 10 times, making 800 rows in all, but every fifth row was a check, making 200 check rows. To determine the experimental error, the 200 check plats are grouped in sets of 10, taking 1 plat from each series, the same as in grouping the strains. This method gives 20 sets of 10 checks each, and the range of experimental error to be allowed for is at once apparent.



FIG. 21.—Row plats at harvest time. Each plat is harvested with a hand sickle and the stake tied into the bundle. The bundles from the row plats that are to be kept pure for seed should be covered with cheese cloth or paper bags.

Another important use of checks is as a standard by which to judge progress, and this judgment can be formed very well if the original stock from which selections were made is used for checks.

Figure 22 illustrates the method of selection when the experimental error is determined by the use of checks. Let the figure illustrate an ideal case where any number of strains are being compared for yield, the yield varying from 200 to 320 pounds. Let line eh represent this variation. A series of check plats shows a variation ranging from 240 to 280, represented by line cj . The mean yield of the checks is

260, with an extreme error of 20 above or below the mean. The limits of error for the line *eh* are shown by the lines *dg* and *fi*. To be sure that a certain strain was better than the check plats its yield must fall outside the line *cl* or be better than 280. In the same way two strains can not be compared without making an allowance of 40. For example, 320 is not surely better than 280, since they both might equal 300, but we are sure 320 is better than anything less than 280. If the extreme variation of checks should equal the variation in strains or varieties, then selection would not be possible. On the other hand, if the error in checks is zero, direct comparison between strains could be made, and small differences would be significant. This illustration emphasizes the importance of knowing the probable experimental error and having it well within the limits of expected variation if results are to be secured by selection.

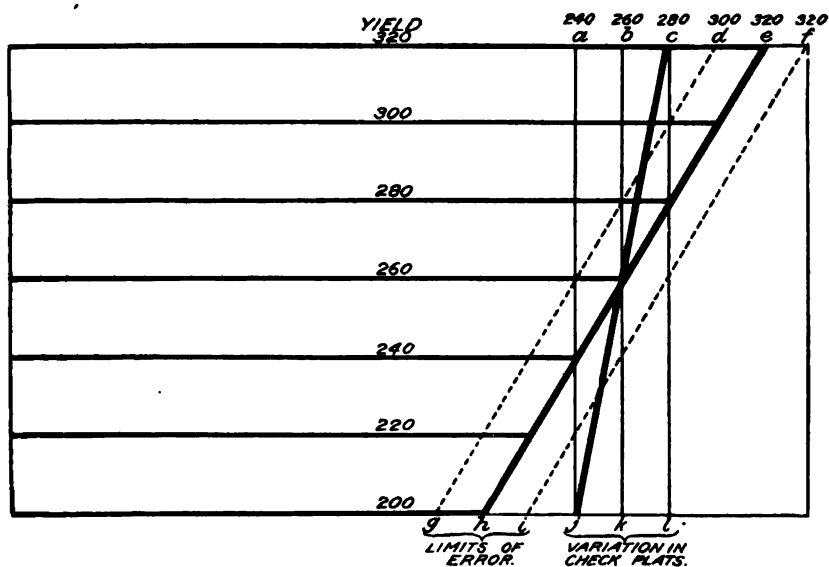


FIG. 22.—Diagram showing the method of selection for yield when the experimental error is known.

ERROR IN CHECK PLATS.

By reference to Table XVI it is seen that where odd and even numbered (alternate) row plats are checked against each other there is a certain experimental error. If this error should be large, it would be unsafe to correct by the checks. For example, if the yield of a certain check variety equals 100, but in series A its yield, due to error, should be 105, and in series B only 95, a correction of yield by these checks would introduce an error of 10 per cent. It might happen that the strain used for checks would be the most variable strain

in use in some particular season, though reliable at other times. For this reason care should be taken to ascertain the experimental error in checks before using them for correction, else a greater error may be introduced by their use than by discarding them.

OTHER PRECAUTIONS AGAINST ERROR.

ACCIDENTAL INJURY TO PLATS.

A problem which always confronts the experimenter at harvest time is what to do with plats injured from some cause, such as the damage of burrowing animals, being partly washed out by floods, etc. Where a plat is obviously injured it should be discarded. To allow for accidents we have adopted the plan of planting one or two extra series to be discarded or used, as is needful, at harvest time. In this way plats accidentally injured may be discarded without disturbing the regular number in the series.

UNEQUAL DRAINAGE.

Unequal effects of winter injury are partly due to unequal distribution of moisture in the soil. Wherever there is a depression run-off water may collect and increase the soil moisture. In some cases, as in a very dry spring, these slight depressions may have an advantage, while at other times these low places suffer from winterkilling. Perfect drainage is very important and can be easily secured by laying off the nursery in slightly elevated beds about 20 feet in width. This bedding can be quickly accomplished by the use of a road grader or road drag (Pl. III, fig. 1).

SUMMARY.

(1) When 14-foot or 16-foot row plats are used as checks or sown in duplicate, great variation is found in yield, owing to natural unequal effects of the environment. When the row plats are repeated only five or six times, the extreme error will still be large, owing to the chance combination of high or low variants.

(2) Systematic repetition constantly reduces error as the number of repetitions increases, but with 16-foot row plats 10 to 20 repetitions must be made, depending on the degree of accuracy desired.

(3) It is probable that the greater the number of strains to be compared the more repetitions will be necessary, because of the greater area they will cover.

(4) Small blocks, 5.5 feet square, give results similar to those of the row plats, except that the reduction of experimental error is somewhat greater as a result of repetition. Blocks repeated 8 to 10 times give results apparently about as accurate as rows repeated 15 to 20 times.

(5) To increase the size of the block, up to a certain limit, rapidly decreases variability; but error can not be indefinitely decreased by continuing to increase the size of the plat, as it can be by repetition.

(6) Variability is not constant from year to year on the same plats.

(7) To alternate with check rows gives a high degree of accuracy, with a few extreme variations, when as high as 10 or more checks are used. The total number of plats required for the same degree of accuracy, however, is greater by this method than by systematic repetition.

(8) To increase the length of the row 4 times decreases deviation about one-half.

(9) By increasing the length of the row or the size of the block, the number of repetitions necessary is decreased, but the total area required to secure the same accuracy is increased. An excellent size, where land is plenty, would be 2 to 4 rods in length for rows, and 5 by 16 feet in area for blocks.

(10) The rate of planting, within certain wide limits, has little influence on yield.

(11) There is some competition between adjacent rows, especially when varieties very different in habit of growth are planted side by side. The use of blocks does away with this source of error.

(12) Pure strains differ in a very marked way in most important characters. High yield in the field is associated with high yield in the nursery plats, and strong straw has a slight relation to size of plant, no relation to size of berry, and varies inversely with the percentage of nitrogen.

(13) Block plats and row plats at the usual rates of seeding will probably correlate more closely with results in field plats than in plats where the plants are spaced, as in centgeners.

(14) Where error is corrected by the system of repetition of plats, check plats should be used for the purpose of determining the experimental error. When the variation in checks equals the variation in strains, no possible selection can be made.

Issued March 11, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 270.

B. T. GALLOWAY, *Chief of Bureau.*

CONTRIBUTIONS TO THE STUDY OF MAIZE DETERIORATION.

BIOCHEMICAL AND TOXICOLOGICAL INVESTIGATIONS
OF *PENICILLIUM PUBERULUM* AND *PENI-
CILLIUM STOLONIFERUM*.

BY

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and Fermentation Investigations.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1913.

BUREAU OF PLANT INDUSTRY.

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Assistant Chief of Bureau, WILLIAM A. TAYLOR.

Editor, J. E. ROCKWELL.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., September 25, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 270 of the series of this Bureau the accompanying manuscript entitled "Contributions to the Study of Maize Deterioration. Biochemical and Toxicological Investigations of *Penicillium Puberulum* and *Penicillium Stoloniferum*." The paper was prepared by Dr. Carl L. Alsberg and Mr. Otis F. Black, Chemical Biologists in the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations, and has been submitted by Dr. R. H. True, Physiologist in Charge, with a view to its publication.

The results of technical laboratory studies of organisms occurring in deteriorated maize, (1) *Penicillium puberulum* Bainier and (2) *Penicillium stoloniferum* Thom, are here presented, demonstrating that these organisms have specific physiological properties. One of these molds is shown to develop toxic substances in maize. Owing to the serious problems now grouping themselves about this important American farm crop, it is believed that the results of this investigation constitute a timely contribution to our information on the subject of the deterioration of maize.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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CONTRIBUTIONS TO THE STUDY OF MAIZE DETERIORATION.

BIOCHEMICAL AND TOXICOLOGICAL INVESTIGATIONS OF *PENICILLIUM PUBERULUM* AND *PENICILLIUM STOLONIFERUM*.

INTRODUCTION.

Whether molds or the products of their growth have an injurious effect on animals is a question which has not yet been conclusively settled. The literature contains many records of alleged intoxications due to these fungi. Certain diseases of men and domesticated animals have been attributed to this cause. Though the solution of this problem is obviously urgent, few serious attempts have been made to identify chemically the alleged toxic substances. The present paper is such a chemical study. Incidental observations on the metabolism of molds have been made and have been recorded because they have a general biological interest and because they may prove useful in characterizing different species physiologically.

The difference of opinion concerning the toxicity of *Penicillium* is probably due not merely to the fact that the earlier investigators studied accidental mixtures of organisms under varying and undefined conditions,¹ but also that complex substrata like corn, wheat, and bread were used for the growth of the organisms. Consequently it is impossible to know whether any of the different substances found were derived from the substratum or were produced by the

¹ Lombroso, Cesare, and Dupré, Francesco. *Indagini chimiche, fisiologiche e terapeutiche sul mais guasto*. Reale Istituto Lombardo di Scienze e Lettere, Rendiconti, s. 2, v. 5, p. 883-884, 1872.

— and Erba, Carlo. *Sulle sostanze stricniche e narcotiche del mais guasto*. Idem, s. 2, v. 9, p. 133-147, 1876.

— Sull' alcaloide del mais guasto. Idem, s. 2, v. 9, p. 433-436, 1876.

— I veleni del mais e la pellagra. Idem, s. 2, v. 9, p. 182-186, 1876.

— I veleni del mais e la loro applicazione all' igiene ed alla terapia. *Rivista Clinica di Bologna*, s. 2, ann. 7, p. 100-112, 1877.

Brugnatelli, T., and Zenoni, E. *Di un alcaloide che si trova nella melica guasta e nel pane di mais ammuffito*. Reale Istituto Lombardo di Scienze e Lettere, Rendiconti, s. 2, v. 9, p. 293-297, 1876.

Palloggio, Pietro. *Materia reagente quale alcaloide, trovata nell' estratto del mais guasto preparato dall' erba*. Idem, s. 2, v. 9, p. 118-121, 1876.

Salmi, Antonio. *Delle alterazioni alle quali soggiace il granturco (Zea mais) e specialmente di quello che ingenera la pellagra*. *Atti della R. Accademia dei Lincei*, s. 3, Memorie della Classe di Scienze Fisiche, Matematiche e Naturali, v. 1, dispensa 2, p. 1009-1141, 1877.

Husmann, Th. *Ueber einige Producte des gefaulten Mais*. Ein Beitrag zur Lehre von den Fäulnissgifte. Nach Versuchen von Dr. Roberto Cortes aus Tumaco in Columbian. *Archiv für Experimentelle Pathologie und Pharmakologie*, Bd. 9, p. 226-228, 1878.

Monsell, G. *Ricerche chimico-tossicologiche intorno ad alcuni campioni di mais per lo studio della pellagra*, Mondovì, 1881, 68 p. (Cited by Gosio.)

organisms. Thus Selmi¹ thought acrolein or a condensation product of acrolein with ammonia was produced, while Lombroso and Dupré,¹ Lombroso and Erba,¹ Brugnattelli and Zenoni,¹ Pelloggio,¹ and Coeytaux² found alkaloids. Though some of these investigators examined the maize or other material employed as substratum, before the development of the organisms, only Lussana and Ciotto³ give sufficient details to inspire confidence in the adequacy of the controls. They found alkaloids in both moldy and sound maize and wheat. In the investigation of maize in progress in this laboratory, of which this bulletin is in part a report, cholin, betain, and bases unidentified as yet have been isolated from sound maize.

The first investigator to use pure cultures in a simple culture medium was Gosio,⁴ who used Raulin's solution. Under these conditions *Penicillium* endowed the culture medium with the power to react like a phenol with weak aqueous ferric-chlorid solutions. A similar observation on *Aspergillus niger* had been made many years before by Raulin,⁵ who found that in the absence of iron this fungus has a similar effect on the culture medium. Raulin attributed the ferric-chlorid reaction present under these conditions to the formation of sulphocyanid. This observation was apparently unknown to Gosio. Recently Javillier and Sauton⁶ have confirmed Raulin's observations, but have doubted that the reaction was due to sulphocyanid. They found, furthermore, that the reaction fails when the organism is grown in the absence of both iron and zinc. Moreover, Raciborski⁶ also obtained the ferric-chlorid reaction with a number of fungi. He concluded that molds may secrete a variety of aromatic substances, for the culture medium may give Millon's reaction and the diazo reaction of Griess. He also found that substances reducing Fehling's solution, ammoniacal silver solution, and ammonium vanadate were formed. He regarded them all as probably products of the protein metabolism of the fungus.

Gosio found further that by administering the culture medium to mice, to rats, to guinea pigs, to rabbits, to cats, or to dogs, symptoms resembling phenol poisoning could be produced. The culture media

¹ Op. cit.

² Coeytaux, A. Notice sur l'huile et la teinture de maïs gâté. *Schweizerische Wochenschrift für Pharmacie*, Jahrg. 18, p. 153-156, 1890.

³ Lussana, Filippo, and Ciotto, Francesco. Su gli alcaloidi del maïs guasto. *Gazzetta Medica Italiana Lombardia*, v. 43 (s. 8, t. 5), p. 522-523, 1883; v. 44 (s. 8, t. 6) p. 82-86, 95-97, 105-106, 122-123, 126-130, 149-150 167-168, 173-179, 196, 243-247, 263-266, 273-276, 283-287, 294-296, 1884.

⁴ Gosio, B. Ricerche batteriologiche e chimiche sulle alterazioni del maïs. *Rivista d'Igiene e Sanità Pubblica*, ann. 7, p. 825-849, 860-888, 1896.

⁵ Cited by Javillier, M., and Sauton, B. Le fer est-il indispensable à la formation des conidies de l'*Aspergillus niger*? *Comptes Rendus de l'Académie des Sciences [Paris]*, t. 153, p. 1177-1180, 1911.

⁶ Raciborski, M. Über die Assimilation der Stickstoffverbindungen durch Pilze. *Bulletin International de l'Académie des Sciences de Cracovie. Classe des Sciences Mathématiques et Naturelles*, ann. 1906, p. 733-770, 1907.

presented other properties characteristic of phenols. Hence, Gosio concluded that phenols were produced by the molds and that the toxicity of the culture media was due to their presence. By means of ether he even succeeded in isolating from the culture medium a small quantity of a crystalline substance giving the ferric-chlorid color reaction. The substance was slightly soluble in cold water, though freely soluble in hot water and in most organic solvents. It failed to react with Fehling's solution or with phenylhydrazin. It contained 62.2 per cent carbon, 6.34 per cent hydrogen, and 28.45 per cent oxygen, corresponding to the empirical formula $C_9H_{10}O_8$. In alcoholic solution ferric chlorid produced an intense blue coloration. In spite of the high melting point, 143° to 144° C., and the failure of Millon's reaction, Gosio regarded the substance as probably *p*-hydro-cumaric acid. Moreover, he presented evidence for the existence in the culture medium of other unisolated phenolic substances. As a result of these researches Gosio proposed ferric chlorid as a reagent for the detection of moldy maize, but stated that its usefulness might be limited to the detection of the molds producing phenols.¹ These discoveries, in the main, were confirmed by others.²

Unfortunately, none of the investigations on green *Penicillium* can be repeated because the organism used was inadequately described. Undoubtedly the different investigators employed different species, for nearly all of them recognized the fact that the quantities of Gosio's toxic phenolic substances varied for different strains. None of them attributed these variations to the use of distinct species, though Ceni and Besta³ did distinguish between toxic and nontoxic forms without, however, adequately differentiating them.

Di Pietro⁴ first showed toxicity to be limited to certain distinct species of *Penicillium*. From moldy maize he isolated *Penicillium brevicaulis*, *P. candidum*, and *P. glaucum*; but stated that "*P. glaucum*" did not mean *P. glaucum* Link, because six quite distinct green species were isolated, none of which is described in Saccardo's *Sylloge*. Of

¹ Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 199, p. 27, 1910.

² Gosio, B., and Ferrati, E. Sull' azione fisiologica dei veleni del mais invaso da alcuni ifomiceti. *Rivista d'Igiene e Sanità Pubblica*, ann. 7, p. 961-981, 1896.

Antonini, G., and Ferrati, E. Sulla tossicità del mais invaso da "*Penicillium glaucum*." *Archivio di Psichiatria, Scienze Penali ed Antropologia Criminale*, v. 24 (s. 2, v. 8), p. 581-585, 1903.

Ceni, Carlo. Le proprietà tossiche di alcuni ifomiceti in rapporto colle stagioni e col ciclo annale dell'endemia pellagrosa. Comunicazione preliminare. *Rivista Pellagologica Italiana*, v. 4, p. 89.

— Idem. Seconda nota preventiva. Comunicazione fatta al III Congresso della Società Italiana di Patologia tantom in Roma, 26-28 Aprile, 1905. *Rivista Pellagologica Italiana*, v. 5, p. 184.

³ Ceni, Carlo, and Besta, Carlo. I *Penicilli* nell' etiologia e patogenesi della pellagra. *Rivista Sperimentale di Freniatria e Medicina Legale delle Alienazioni Mentali*, v. 29, p. 741-815, 1903.

— Die pathogenen Eigenschaften des *Aspergillus niger* mit Bezug auf die Genese der Pellagra. *Beiträge zur Pathologischen Anatomie und zur Allgemeinen Pathologie*, Bd. 37, p. 578-589, 1905.

⁴ Di Pietro, Melchiorre. Sui veleni di alcune muffe. *Annali d'Igiene Sperimentale*, v. 12 (n. s.), p. 314-365, 1902.

— Intorno al "*Penicillio tossico*." *Rivista Pellagologica Italiana*, v. 3, p. 221, 1903.

all the organisms isolated from maize by Di Pietro only one of the six species of "*P. glaucum*" proved to be toxic. The published description of the organism ¹ was not accessible in Washington.

Gosio ² replied to these papers of Di Pietro, stating that he had previously pointed out ³ that different strains vary greatly in their power to produce toxic substances. Though he studied Di Pietro's organism he refused to acknowledge that Di Pietro's observations had any further significance and was inclined to think that *Penicillium glaucum*, like pathogenic bacteria, varies in virulence.

Di Pietro believed that the toxic principle was a glucosid,⁴ although his reasons were not clearly stated, for this toxic principle was not obtained in a state of purity. All that showed glucosidic properties was the reduction of Fehling's solution by the extracts and the diminution of toxicity by heating with hydrochloric acid. Though Gosio's substances were excreted into the medium and those of Di Pietro were confined to the spores, both substances gave a ferric-chlorid color reaction.

Sturli ⁵ also found that an organism isolated from polenta or maize mush from Bukowina did not render the medium toxic, while the mycelium was very toxic. He believed it premature to draw any conclusions concerning the chemical properties of the toxic substances, calling the toxic material "indifferent substances."

Possibly the descriptions of all of the green species of *Penicillium* used in previous investigations are inadequate because the medical bacteriologist is usually insufficiently acquainted with molds.⁶ The identification of the species can be intrusted only to the skilled mycologist.⁷ One of the consequences of the study of molds by mycologists has been that Thom has found it necessary to disregard the species *Penicillium glaucum* Link, because Link's description is applicable to many forms.⁸ Hence the identity of many of the molds used hitherto in toxicological investigations can no longer be established. Di Pietro was therefore right in his belief that a

¹ Di Pietro, Melchiorre. Studio morfologico e biologico sul *Penicillium glaucum* (var. tossica) Teramo. 1904.

² Gosio, B. Per l'etiologia della pellagra. Rivista Pellagologica Italiana, v. 3, p. 177, 1903.

³ Gosio, B. Ricerche batteriologiche e chimiche sulle alterazioni del mais. Rivista d'Igiene e Sanità Pubblica, ann. 7, p. 325-349, 360-383, 1896.

⁴ Di Pietro, Melchiorre. Glucosidi di elevato potere tossico trovato nelle spore del *Penicillium glaucum*. Rivista Pellagologica Italiana, v. 2, p. 63, 1902.

⁵ Sturli, Adriano. Ueber ein in Schimmelpilzen (*Penicillium glaucum*) vorkommendes Gift. Wiener Klinische Wochenschrift, Jahrg., p. 711-714, 1908.

⁶ Tiraboschi, C. Studi sugli ifomiceti parassiti del granturco guasto. Atti del Terzo Congresso Pellagologico Italiano, Milano, 24-25-26, Settembre, 1906, p. 123. 1907.

⁷ Nikitinsky, Jacob. Über die Beeinflussung der Entwicklung einiger Schimmelpilze durch ihre Stoffwechselprodukte. Jahrbücher für Wissenschaftliche Botanik, Bd. 40, p. 3, footnote, 1904.

Wehmer, C. Notiz über Rhizopus-Arten. Berichte der Deutschen Botanischen Gesellschaft, Bd. 23, p. 547-549, 1911.

⁸ Thom, Charles. Cultural studies of species of *Penicillium*. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 118, 1910.

number of green species exist. Moreover Dox¹ has shown that biochemically the different species vary and has asserted that many of the conflicting statements in the literature, especially those concerning the proteolytic enzymes, may be explained on the assumption that different organisms were used under the same name. Nikitinsky² also suspected that *Penicillium glaucum* and *P. griseum* comprised a number of physiological varieties because of their varying power to form or to withstand acid.

For this investigation the genus *Penicillium* was chosen, because it is well systematized in the recent monograph of Thom.³ Five species inhabiting spoiled maize in the United States were obtained from Dr. Thom and cultivated separately by Dr. Erwin F. Smith. Without such help this investigation could hardly have been undertaken. Seventy-five to one hundred grams of air-dry, white corn meal were sterilized, usually in the autoclave, in 1-liter Erlenmeyer flasks, with enough water to form a layer of the mixture over the bottom about 3.75 centimeters thick. These flasks were observed for several days, to detect inadequate sterilization, when the sterile flasks were inoculated by Dr. Smith with spores of fresh cultures. The cultures were allowed to develop at room temperature in diffused light for 34 days, from April 12 to May 16, 1910. All developed spores.

To determine toxicity each culture was digested 16 hours with 500 cubic centimeters of 95 per cent alcohol. The extract was filtered and all alcohol from 50 cubic centimeters, corresponding to 6 to 10 grams of meal, evaporated on the steam bath. The residue was filtered, yielding usually about 1 cubic centimeter of an acid solution. One-half of this filtrate was then injected subcutaneously into mice weighing 20 grams each. The extract from one of the cultures caused death in about 10 hours; another in 7 hours; the others had no harmful effect. Neither the convulsions nor the spasms described by Gosio and Ferrati⁴ were observed. The mice seemed merely very sick and died quietly. When the dosage was larger, initial convulsions with paralysis of the fore limbs were produced. These symptoms soon passed away and the mice died as did those that had received smaller dosages. The fatal dose for both cultures was more than ten times that of Gosio's cultures, so that neither is likely to have been identical with his culture.

As a control, a culture flask containing corn-meal mush in the same quantity was left uninoculated. After standing sterile during the

¹ Dox, A. W. The intracellular enzymes of *Penicillium* and *Aspergillus*, with special reference to those of *Penicillium camemberti*. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 120, p. 36, 1910.

² Nikitinsky, J. Op. cit.

³ Thom, Charles. Op. cit.

⁴ Gosio, B., and Ferrati, E. Sull' azione fisiologica dei veleni del mais invaso da alcuni ifomiceti. Rivista d'Igiene e Sanità Pubblica, ann. 7, p. 961-961, 1896.

growth of the organisms in the other flasks it was, simultaneously with them, extracted by the same proceeding and tested in the same way for toxicity. It did not produce any symptoms in the mice. Consequently, the effects observed were the result of the growth of the molds.

Because the toxic substances are believed by Gosio to be identical with those giving color reactions with ferric chlorid the cultures were tested with this reagent. Fifty cubic centimeters of the alcoholic extracts were neutralized and evaporated nearly to dryness on the steam bath. The residues were then extracted with water weakly acidulated with hydrochloric acid and filtered. The clear filtrate was extracted with a relatively large volume of ether and the ethereal extract evaporated to dryness. The residue from the ether was extracted with water before testing with a very weak solution of ferric chlorid. In one case a weak but distinctly reddish brown color was obtained. One culture gave no color. Two gave a slight brown coloration. Another culture, after the evaporation of the alcohol, gave a brick-red, watery extract, which, on neutralization, turned to a deep-claret color. Therefore, in this culture, it was impossible by this method to detect phenols, if present. The organism producing this dye is the one referred to by Thom¹ as having been found by Prof. F. D. Heald on maize and as being either identical with or very closely related to *Penicillium purpurogenum* O. Stoll. It has been possible to isolate the dyestuff and its description is reserved for a future publication.

The culture which gave on extraction the brownish red coloration with ferric chlorid was the one that killed the mice in 10 hours. It was identified as *Penicillium puberulum* Bainier, and a detailed study of this species is here given.

PENICILLIUM PUBERULUM.

Penicillium puberulum Bainier was originally isolated from corn by Prof. F. D. Heald, then of Lincoln, Nebr., now of Austin, Tex. The culture obtained from Dr. Thom is No. 45 of his collection, and had been grown on a 3 per cent sugar decoction of beans. Dr. Thom states that if it is not identical with *P. puberulum* of Bainier² it is very closely related to it. He has very kindly furnished the following description:

Colonies in Czapek's solution agar, dull bluish green to green, velvety, spreading slowly upon the substratum, zonate at the margin in older colonies, with an outer band of submerged mycelium; mycelium yellowish or greenish to tan below (as viewed from below); agar uncolored; odor weak but noticeable; conidiophores

¹ Thom, Charles. Op. cit., p. 36.

² Bainier, G. Sur dix espèces nouvelles de *Penicillium* et sur le genre *G. graphiopsis*. Bulletin, Société Mycologique de France, t. 23, 1907, p. 16. 1908.



FLASK SHOWING TWELVE DAYS' GROWTH OF *PENICILLIUM PUBEULUM* ON RAULIN'S MEDIUM.

mostly arising separately from the submerged hyphae, short—up to $100\ \mu$ long by $3.5\ \mu$ diameter, crowded, with walls more or less rough with delicate warts or granules or smooth; conidial fructifications becoming more or less loosely columnar masses 20 to $30\ \mu$ long and consisting of the main conidiophore, a primary branch or verticil of branches, secondary verticils of branchlets, all swollen or enlarged at apex, bearing verticils of conidiferous cells 8.5 by 2 to $2.5\ \mu$, producing very long chains of conidia; conidia elliptical to globose, 3 to $3.5\ \mu$ diameter when ripe, smooth, swelling in germination to 5 to $8\ \mu$ and germinating by one or two tubes $3\ \mu$ in diameter—when two tubes are present these are separated by 180° —appear at the points of contact of the conidia in the chains (where the walls are thinner); colonies liquefy simple gelatin, producing a trace of brown color in the liquid and an alkaline reaction to litmus, and become dark or smoky in color in media without sugar; with lactose gelatin no acid is produced; in rich substrata under humid conditions colonies become overgrown with white floccose sterile mycelium after the conidial areas are matured; colonies grown readily in all common media. Collected by Prof. F. D. Heald in Nebraska upon decaying Indian corn (*Zea mays*).

Note.—In measuring conidiophores I measure from the point of origin at the surface of the substratum to the lowest branch of the fruit. Simple gelatin here means 15 per cent of gelatin in distilled water.

Plate I shows a culture of *Penicillium puberulum* Bainier after 12 days' growth on Raulin's medium.

In investigating the toxic properties of this mold, the injurious effects were found due not to the acidity¹ of the extracts of the culture, as prepared above, but to some specific substance. This is shown in the following experiment:

Fifty cubic centimeters of the alcoholic extract of the corn-meal cultures were carefully neutralized with sodium carbonate before concentration. The solution thus obtained was not toxic. As loss of toxicity might be due either to neutralization of acid or to destruction of the toxic substance by heat in neutral solution, fresh extracts were tested by injecting the ethereal extract neutralized after concentrating. The mice died as before, showing that the toxicity was due to some toxic material stable only in acid solution.

PENICILLIC ACID FROM PENICILLIUM PUBERULUM.

Cultures of *Penicillium puberulum* Bainier were grown about a month on Raulin's medium. At the end of this period the medium was still acid, but far less toxic than the extracts prepared from the cultures on corn-meal mush. However, the medium gave the color reaction with ferric chlorid. Extracts of the mycelium were neither toxic nor did they give the ferric-chlorid reaction. The substance responsible for this reaction did not occur in the mycelium. It was extracted from the medium with chloroform and crystallized on concentration of the solvent. Recrystallized from hot water it forms large, transparent, biaxial, monoclinic or triclinic, rhombic crystals

¹ Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 199, p. 30, 1910.

with good cleavage normal to an axis. The substance burns without ash, contains no nitrogen, and is not optically active; but it is acid to litmus and phenolphthalein and decomposes carbonates at ordinary temperatures.

For purposes of analysis the material was purified with bone black and twice recrystallized from hot water. Recrystallization from alcohol, water, ether, benzol, or chloroform and precipitation from ethereal solution by petroleum ether failed to remove traces of a yellowish color or to change the melting point.

The crystals from water have a melting point of 64° to 65° C., uncorrected, and effloresce rapidly in the air. The anhydrous substance is a white powder, melting sharply at 86° to 87° C., uncorrected, without decomposition. The water of crystallization was determined by pressing the crystals dry between filter paper, weighing rapidly, and drying to constant weight at room temperature under diminished pressure, with sulphuric acid as dehydrating agent. Heated to 50° to 60° C. the material suffered no further loss in weight. The other analyses made were the determinations of the content of carbon and hydrogen, of the magnesium content of the salt, and the titration of the free acid with standard alkali. The last two determinations furnished data for the calculation of the molecular weight. The substance was dried for these analyses in the manner above given. The analytical data follow:

TABLE I.—*Analyses of penicillic acid.*

Weight of substance (grams).	CO ₂ (grams).	H ₂ O (grams).	C (per cent).	H (per cent).	Water of crystal- lization.		MgSO ₄ (grams).	Mg (per cent).	N/10KOH (c. c.).
					Grams.	Per cent.			
0.2268 (anhydrous substance).....	0.4649	0.1165	55.90	5.71					
0.2017 (anhydrous substance).....	.4135	.1081	55.91	5.68					
0.2215 (anhydrous substance).....									12.97
0.3460 (crystals from water).....					0.0577	16.6			
0.2664 (crystals from water).....					.0475	17.8			
0.2238 (anhydrous magnesium salt)....							0.0750	6.78	
0.1923 (anhydrous magnesium salt)....							.0639	6.72	
Average.....			55.90	5.69		17.2		6.75	

Calculated for C₈H₁₀O₄: carbon, 56.6 per cent; hydrogen, 5.89 per cent.

Foundcarbon, 55.90 per cent; hydrogen, 5.69 per cent.

Calculated for C₈H₁₀O₄, 2H₂O: water, 17.48 per cent.

Foundwater, 17.20 per cent.

A molecular weight determination by the elevation of the boiling point in chloroform solution gave the results shown in Table II.

TABLE II.—*Ebullioscopic determination of molecular weight of penicillic acid.*

Weight of substance (grams).	Weight of solvent (grams).	Rise of boiling point (°C.).	Molecular weight.
0.1802....	26.24	0.170	146
.2091....	26.24	.191	153
.2349....	26.24	.177	177
Average..	.....	.....	162

Molecular weight calculated for $C_8H_{10}O_4$	170
Molecular weight found from titration.....	170.4
Molecular weight found from magnesium content of salt.....	168.3
Molecular weight found by boiling-point elevation.....	162

From the data at hand the formula $C_8H_{10}O_4$ may be provisionally assigned to this substance. It has not been possible to identify it with any known substance, nor has it as yet been possible to determine its constitution. Tentatively, the name penicillic acid is suggested for it.

Penicillic acid is soluble in alcohol, ether, benzol, and chloroform, but insoluble in petroleum ether. In cold water it is soluble in the proportion of about 2 to 100, but readily soluble in hot water. From its aqueous solutions it can be extracted most readily by chloroform. Olive oil dissolves it but slightly and does not extract it from aqueous solution. It decomposes carbonates. It has a somewhat salty, slightly bitter-sweet taste, and is somewhat irritating to mucous membranes. It produces a rather persistent sensation of burning at the fauces. It absorbs bromin without forming an insoluble compound; reduces Fehling's solution when heated, and ammoniacal silver at room temperature. It is fairly resistant to acids, for it may be heated with weak acid without undergoing decomposition, and it is not charred by concentrated sulphuric acid. It is, however, very sensitive to alkali. Fixed alkalis turn the solution yellow. Dilute ammonia gradually converts it into a deep-red dye, resembling that obtained from orcin by ammonia. The color with ammonia is so similar to that of the dyestuff obtained from *Penicillium purpurogenum*¹ that similarity in constitution between the two substances is at once suggested.

The magnesium salt forms transparent, rapidly efflorescent plates, drying to a white powder. It is very soluble in water and alcohol and is not readily precipitated from its alcoholic solution by ether.

¹ Cf. *supra*, p. 12.

The salt was prepared by digesting an aqueous solution of the pure substance on the water bath with magnesium carbonate, filtering, and concentrating to dryness in a desiccator. It contains about 30 per cent of water of crystallization. Because of its great solubility it was not further purified for analysis, but dried to constant weight in vacuo under sulphuric acid at room temperature. The salts of calcium, barium, sodium, ammonium, potassium, and copper are also very soluble in water. Their solutions dry down to varnishes. The silver salt is not stable. The lead salt is insoluble in water and amorphous.

Aqueous solutions of penicillic acid are not changed by very dilute ferric chlorid till after some time, when they gradually turn brownish red. Either it is not a simple phenol and must first be oxidized, or the action of the ferric chlorid is inhibited for a time by the reducing power of the substance. The reaction is not so delicate as that with ammonia. The formation of the color with ferric chlorid is very like that obtained by the oxidation of β -oxybutyric acid by means of weak peroxid of hydrogen containing traces of ferric chlorid.¹ Penicillic acid also gives the color under these conditions. The reaction carried out with the aid of peroxid of hydrogen is very much more delicate than that without the peroxid of hydrogen. Alcoholic solutions do not give a color with ferric chlorid. Aqueous solutions give no color with calcium hypochlorite. Nickel and cobalt chlorid give no color reaction.

Because of the observations of Brugnatelli and Zenoni² on the occurrence of strychninlike alkaloids in moldy corn, reactions characteristic for strychnin were tried. (1) A few crystals treated with concentrated sulphuric acid gave only a faint yellow color. On adding a small crystal of bichromate of potassium to the mixture a weak green color from reduced bichromate developed. The reaction was therefore negative. (2) A few crystals were treated with a little concentrated nitric acid. No color developed. On warming, a yellow color appeared, which, as the acid was evaporated, turned pale orange. After cooling, an orange-colored sticky residue remained, which when treated with ammonia water turned a little darker orange. Hence, both these tests for strychnin proved negative.

If an aqueous solution of the substance be boiled under a reflux condenser with barium hydrate, barium carbonate is the only insoluble product formed. If the solution be then distilled after acidifying, a small quantity of delicate needles with an odor akin to cumarin and vanillin may be separated from the distillate by extracting with

¹ Black, O. F. The detection and quantitative determination of β -oxybutyric acid in the urine. *Journal of Biological Chemistry*, v. 5, p. 207-210, 1908.

² Brugnatelli, T., and Zenoni, E. Di un alcaloide che si trova nella melica guasta e nel pane di mais ammuffito. *Reale Istituto Lombardo di Scienze e Lettere, Rendiconti*, s. 2, v. 9, p. 293-297, 1876.

ether. They gave no color with ferric chlorid. Gosio obtained extracts with an odor of cumarin from cultures of *Aspergillus*.¹

The dry crystals heated with concentrated hydrochloric acid form a yellow oil, showing a tendency to crystallize when chilled. The oil is insoluble in water and with ferric chlorid gives a dark-red color at once, not weakly and gradually like the mother substance.

Lieberman's reaction produced a beautiful carmine-red coloration. Millon's reaction is negative. In performing Piria's reaction the substance when dissolved in warm, concentrated sulphuric acid turned yellow, then red; and when diluted with water gave a heavy, amorphous-red precipitate, which was not obtained crystalline from alcoholic solutions. This is evidently an insoluble sulphonic acid. It was removed by filtration and the filtrate neutralized with barium carbonate. The barium sulphate was removed and the clear filtrate tested with a little weak ferric chlorid. A dirty red color developed, quite different from the fine violet color obtained with tyrosin. It is doubtful whether this test has the significance of Piria's reaction, since a similar color is obtained after heating penicillic acid with dilute sulphuric or hydrochloric acid without subsequently neutralizing.

By the method suggested by Schotten and Baumann no crystalline benzoyl derivative was obtained. No crystalline oxime could be prepared. A small quantity of a crystalline derivative was obtained by heating with acetic anhydrid. Crystalline ethyl ester was also prepared by heating in absolute alcohol with a little dry hydrochloric acid. Heating an aqueous solution with phenylhydrazin hydrochlorid and sodium acetate caused decomposition, as shown by the evolution of gas. Lemon-yellow prisms were formed, which were recrystallized from hot alcohol until a constant melting point, 171° C., uncorrected, without decomposition, was obtained.

The determination of carbon and hydrogen in these yellow crystals by combustion gave the following results:

Weight of substance burned. 0.2103 gram.

Weight of CO₂5655 gram; C, 73.34 per cent.

Weight of H₂O1429 gram; H, 7.56 per cent.

From these figures no formula could be calculated which might be derived from the original substance. It is probably a compound formed by the condensation of phenylhydrazin with a decomposition product. With methylphenylhydrazin nothing crystalline could be obtained. With an excess of nitrophenylhydrazin and acetic acid a red crystalline substance separates, which was not further studied.

Penicillic acid seems to be a substance not hitherto described. Hydroxyphenylglycolic acid would have a similar formula. It is

¹ Gosio, B. Mutamento de chimismo isomietico in rapporto all' alta e bassa fermentazione. Atti del Quarto Congresso Pellagologico Italiano, Udine, 23-24-25 Settembre, 1909, p. 65. 1910.

not known and would in all probability give Millon's reaction. Certain of the lichen acids found hitherto only in lichens and the substance of Gosio cited above have similar empirical formulæ and properties. Not only have some of the lichen acids empirical formulæ resembling penicillic acid, but penicillic acid resembles them in its chemical behavior. Lichen acids are stable in acid solution, but are often decomposed by alkalis to form dyestuffs, as is also the case with penicillic acid. Some of the dyestuffs in common use, like orseille and litmus, are formed in this way. Most of them are decomposed by hot barium hydrate. Some of them are bitter and irritating, often much more so than penicillic acid. Some are derivatives of phenolic substances like orcin or divarin. The fact that penicillic acid forms a sulphonic acid insoluble in water and yields a dye when subjected to Lieberman's reaction also indicates that it contains a phenol nucleus. Lichen acids of this constitution turn red when treated with ammonia, like penicillic acid. Many of them give color reactions with ferric chlorid. The evidence thus far at hand decidedly indicates that penicillic acid may eventually prove to belong to this class of compounds.¹

However, aliphatic formulæ are possible. The propyl esters of diacetylcarbonic, glyoxylpropionic, and acetylpyruvic acids would have very similar formulæ and, presumably, at least some of the characteristics of penicillic acid. Should penicillic acid ultimately prove to be a substance of this general type it would still in some ways resemble certain of the lichen acids; for example, vulpinic acid, which is an inner anhydrid of diphenylketipinnic acid.

If penicillic acid is related to the lichen acids its formation by the fungus is not strange, since lichens are symbiotic growths composed of fungi and algæ. These observations would then acquire biological interest, since they indicate that lichen acids are produced by the metabolism of the fungous part of the symbiotic lichen rather than by that of the alga. Tobler² concluded that lichen acids are solely the product of symbiosis, because a number of fungi from lichens grown separately without algæ formed no lichen acids. Since the formation of penicillic acid is so very dependent upon a number of conditions, it may well be that Tobler did not find lichen acids because he did not happen to employ the necessary environmental conditions.

The penicillic acid described in this paper is not the substance obtained by Gosio, as shown by the fact that the latter gives a dif-

¹ Hesse, O. Beitrag zur Kenntnis der Flechten und ihrer charakteristischen Bestandteile. *Journal für Praktische Chemie*, n. F., Bd. 83, p. 22-96, 1911.

² Tobler, F. Das physiologische Gleichgewicht von Pilz und Alge in den Flechten. *Berichte der Deutschen Botanischen Gesellschaft*, Bd. 27, p. 421-427, 1909.

— Zur Ernährungsphysiologie der Flechten. *Berichte der Deutschen Botanischen Gesellschaft*, Bd. 26, p. 3-12, 1911.

ferent color with ferric chlorid, that it is less soluble in cold water, and that it has a higher melting point, properties in which it resembles lichen acids even more than penicillic acid does.

Nevertheless, the properties and formulæ of the two substances are so similar that some genetic relationship between them is very probable. This possibility gains likelihood from the fact, demonstrated by Gosio, that in addition to the substance isolated by him other similar ones were present giving different colors with ferric chlorid. Moreover, in his cultures the ferric-chlorid reaction varied both in intensity and quality of color. The extract of only 5 to 10 cubic centimeters of culture fluid of some cultures gave a reaction with ferric chlorid, while others required 50 to 100 cubic centimeters.

Evidence of the occurrence of other substances was encountered in the course of this investigation. Some of the culture fluid which had been exhausted by extraction with chloroform was dehydrated by treating with plaster of Paris. The dry powdered mixture was extracted with chloroform and the chloroform evaporated. The residue with an odor like cresol consisted of a few yellowish crystals in a reddish oil. The material was somewhat toxic.

Other evidences in the same direction consist of observations made upon corn spoiled naturally by unidentified green molds and giving positive ferric-chlorid reactions. In every sample encountered in this laboratory the reaction appeared at once, not gradually, as with penicillic acid. The few attempts made to isolate penicillic acid from some of these samples failed, although the acid could readily be isolated from corn inoculated with *Penicillium puberulum*. Undoubtedly in the samples substances other than penicillic acid were responsible for the ferric-chlorid reaction.

Another indication of the presence in the culture fluids of unidentified substances is the considerable acidity of the culture fluids. Four hundred and eighty-five cubic centimeters of a four weeks' culture required 92.15 cubic centimeters n/10 sodium hydroxid for neutralization. From 485 cubic centimeters of this culture 0.2 of a gram of penicillic acid was isolated, equivalent to 11.1 cubic centimeters of n/10 alkali. The acidity of fresh Raulin's solution is due entirely to the tartaric acid, but at the end of growth no tartaric acid could be isolated. On the assumption that all the tartaric acid had been consumed and that all the penicillic acid had been extracted, a considerable quantity of acid remained undetermined.

Furthermore, there are great differences in the metabolism of the organism used by Gosio and of *Penicillium puberulum*. The former produced acetaldehyde, a little acetic acid, glycerin, and succinic acid;¹ the latter produced no more than traces of these substances.

¹ Gosio, B. Ricerche batteriologiche e chimiche sulle alterazioni del mais. Rivista d'Igiene e Sanità Pubblica, ann. 7, p. 874, 1906.

Finally, a conclusive argument is the fact that, as shown below, it has been possible to isolate in quantity from another species, *P. stoloniferum* Thom, a new acid more nearly resembling Gosio's substance than penicillic acid does. These facts do not support Paladino-Blandini's ¹ suggestion that the toxic material formed by a large number of fungi is identical.

Di Pietro's toxic principle also differs from penicillic acid in its insolubility in water and in the fact that with ferric chlorid it gave a grass-green, "verda-erba," color instead of a reddish one.² Di Pietro³ believed the toxic principle to be a glucosid. His evidence for this view, as above stated, seems to have been based on the fact that the reducing power of his toxic extracts was lost by boiling in acid, but was not lost in neutral solution. But this is also true of penicillic acid, though there is no question of its being a glucosid. If it contained a carbohydrate it would char with concentrated sulphuric acid and would in all probability be optically active. It is not necessary for a substance to be a glucosid in order to have reducing power. Many lichen acids, for example, have this power. In another important way Di Pietro's extracts resemble penicillic acid. He says that the "glucosid" itself gives the reaction with ferric chlorid only very weakly and gradually. This is exactly the behavior of penicillic acid. If, however, says Di Pietro, its sugar be split off by hydrolysis an aromatic acid is set free, giving the ferric-chlorid reaction at once. Penicillic acid behaves in quite the same way when heated with mineral acid. It is not necessary to assume that either substance is a glucosid. Treatment with acid might merely saponify an ester. It is not necessary to assume, as does Di Pietro, that the substance giving the color is present in three forms, as free aromatic acid, as a salt of the acid, giving the reaction only after acidifying, and as a glucosid. There are so many resemblances between Di Pietro's extracts and penicillic acid that the question involuntarily suggests itself whether his extracts were not mixtures of an unknown very toxic substance and penicillic acid or some very closely related substance. Di Pietro's "glucosid," Gosio's substance, and penicillic acid equally resemble lichen acids. It does not necessarily follow that the very toxic substance or substances of the extract were responsible for the "glucosid" or ferric-chlorid reactions.

CONDITIONS OF PENICILLIC-ACID FORMATION.

On Raulin's medium penicillic acid seems to accumulate only at very definite oxygen tensions. Both a full and a very scanty supply

¹ Paladino-Blandini, A. Tossici di funghi. Archivio di Farmacologia Sperimentale e Scienze Affini, v. 5, p. 605-604, 1908.

² Di Pietro, Melchiorre. Intorno al "Penicillio tossico." Rivista Fisiologica Italiana, v. 3, p. 271, 1903.

³ Di Pietro, Melchiorre. Glucosidi di elevato potere tossico trovati nelle spore del *Penicillium glaucum*. Rivista Fisiologica Italiana, v. 2, p. 63, 1902.

of air are unfavorable. When to insure good aeration the organism was grown in rectangular quart bottles, known in the trade as "Long Blakes," turned on their sides and containing about 200 cubic centimeters of medium, no penicillic acid could be found except traces in cultures less than a week old. Under these conditions¹ the exposed surface of the medium is relatively great and the aeration is good because the neck of the bottle is only about 1 centimeter above the surface. It was hoped that under these conditions the growth of mycelium would be more rapid and the yield of penicillic acid greater than in the 2-liter Erlenmeyer flasks, in which the same amount of medium offers far less surface and the carbonic acid must diffuse upward more than 20 centimeters before escaping from the tightly plugged neck of the flask. Growth was actually better in the bottles, but the yields of penicillic acid were insignificant. Perhaps the good aeration accounts for the latter phenomenon, since penicillic acid is easily oxidized and since even in the Erlenmeyer flasks the yields were poor when they were very loosely plugged with cotton. On the other hand, too poor a supply of air also prevents the formation of penicillic acid, as was shown when the supply was almost completely cut off by tying thin rubber sheeting over the necks of flasks and bottles. This deficiency of yield may be due to the fact that, even after a month, growth is scanty and without spore formation, though it is somewhat better in the bottles than in the flasks. The culture medium remained white and transparent. When the seal was removed from one of the bottles, growth and spore formation became rapid. Within 24 hours the medium turned quite dark. After six days a very small quantity of penicillic acid could be isolated—rather more than was obtained from the 6-day control bottle that had never been sealed. The flasks and bottles that remained sealed failed to develop more than a trace of penicillic acid or of alcohol, even after two months, though more mycelium gradually developed.

This influence of aeration on the quality of the metabolism of *Penicillium* has not hitherto been noted. It furnishes a further explanation for some of the discordant results obtained with *Penicillium*. It shows, moreover, that the ferric-chlorid reaction when negative need not, as some have thought, give reliable information concerning the toxicity of a fungus. Under special conditions of oxygen supply, the reaction may become positive. Species of *Penicillium* which have not been found to give the reaction² will have to be reinvestigated under definite conditions of oxygen tension.

From media which are alkaline or become so, penicillic acid can not be isolated, perhaps because it is sensitive to alkali. Raulin's medium

¹ This method was very kindly suggested by Dr. Hideyo Noguchi, of the Rockefeller Institute of New York.

² Cf. *supra*, p. 12.

is such when deprived of tartaric acid, or when it contains an equivalent amount of sodium acetate instead of tartaric acid, or when it contains 1 per cent of Witte's peptone as the source of nitrogen. Tartaric acid itself is unessential, since succinic acid may be substituted for it without changing the quantity of penicillic acid formed. The failure to find penicillic acid on peptone medium is not in harmony with the observation of Paladino-Blandini¹ that toxic phenolic substances are most abundantly formed on media containing nitrogen in the form of peptone.

The form in which nitrogen is offered may also be of influence, since when tyrosin or leucin were the only source of nitrogen no penicillic acid was detected. As these experiments were performed before the effect of the air supply was known, they are not conclusive. At any rate the absence of the acid from the tyrosin culture is remarkable, as penicillic acid is probably also an aromatic compound. The suggestion advanced by Audenino,² that some of the phenolic substances found in spoiled maize may be derived from the phenylalanin of the zein, does not receive support from these experiments on tyrosin.

On corn-meal mush the organism grew faster and fruited sooner than on Raulin's medium. Penicillic acid was formed, though the quantities extracted were decidedly smaller than those from Raulin's medium, perhaps because of the greater difficulties of purification. The alcoholic extract of the mush on evaporation left a red oil, like that reported by Lombroso.³ From the water extract of the oil the acid crystallized on concentrating and cooling. These cultures gave but a weak or even negative ferric-chlorid reaction, showing that in detecting moldiness the unmodified reaction of Gosio is either not delicate enough or is inhibited by other substances present.

It is therefore evident that the amount of penicillic acid formed varies greatly with the conditions of growth. From 700 cubic centimeters of medium from the 2-liter, tightly plugged, Erlenmeyer flasks small quantities were separable at the end of the first week, about 0.1 gram at the end of the second, 0.2 gram the third, and 0.25 gram at the end of the fourth week, making the final concentration about 1 to 2,000. The method of separation probably does not isolate all the substance present.

TOXICITY OF PENICILLIC ACID.

Penicillic acid contains more oxygen than the material isolated by Gosio. This may explain why the former is toxic and the latter is

¹ Paladino-Blandini, A. *Tossici di ifomocisti*. *Archivio di Farmacologia Sperimentale e Scienze Affini*, v. 5, p. 606-664, 1906.

² Audenino, E. *Etiologia della pellagra*. *Atti del Quarto Congresso Pellagologico Italiano*, Udine, 23-24-25 Settembre, 1909, p. 41. 1910.

³ Lombroso, Cesare, and Erba, Carlo. *Sulle sostanze stricniche e narcotiche del mais guasto*. *Reale Istituto Lombardo, Rendiconti*, s. 2, v. 9, p. 133-147, 1876.

not, for it is a well-known fact that the introduction of hydroxyl into the benzol ring increases toxicity.¹ Benzol and phenol are good examples of this phenomenon.

The toxicity of penicillic acid is shown by the following experiments: When 7 milligrams of penicillic acid, dissolved in 0.5 cubic centimeter of physiological salt solution, are injected subcutaneously into a mouse of about 20 grams weight, convulsions and paralysis, particularly of the forelegs, develop very quickly, so that the head and forward portion of the body fall down on the ground while the hind quarters are still struggling and kicking. After a while these violent symptoms wear off and the animal is quiet; usually it assumes a sitting posture, with fur ruffled, the vessels of the ears congested, muzzle twitching, and diaphragm contracting spasmodically, so that the mouse has the appearance of retching. The animal might be regarded as recovering. However, death usually comes quietly in 5 to 12 hours. Apparently the symptoms are identical with those produced by the extracts of the corn cultures. A smaller dose (5 milligrams) causes the initial symptoms of convulsions and paralysis, but the animal usually recovers. Death is not due to acid action, for the same symptoms follow the injection of the same dose in solutions neutralized with sodium hydroxid. Moreover, the injection of equivalent quantities of hydrochloric or sulphuric acid is without serious effect. The fatal dose for mice is therefore about 0.3 to 0.35 gram per kilogram when injected subcutaneously.

With a stomach tube a guinea pig of 525 grams weight was fed 10 cubic centimeters of a 2 per cent solution of penicillic acid in warm normal saline solution. In the course of half an hour the animal became weak, particularly in the hind legs, and lay prone on the abdomen. When turned on the back he remained in that position. An hour later he began to recover. When returned to the cage he sat quietly without eating. The following day the weight had dropped to 495 grams, and on the second day to 470 grams. On the third day the weight rose to 485 grams and the animal recovered.

Another guinea pig of 410 grams weight received subcutaneously in the region of the spinal column 1.8 cubic centimeters of 2 per cent penicillic acid in warm normal saline solution. At first the effects were not marked. The animal remained quiet with fur bristling. Then a little weakness of the hind limbs developed. A second injection of 2 cubic centimeters was made 4½ hours later beneath the skin of the abdomen. In both injections an appreciable amount of the injected liquid was lost by oozing through the needle puncture. The animal was observed for 2½ hours after the second injection. No change in its condition was noted. The following morning it was found dead. Autopsy revealed nothing but rather extensive serous

¹ Fränkel, Sigmund. Die Arzneimittel-Synthese, Aufl. 2, Berlin, 1906, p. 53.

effusions at the sites of injection. There was neither pus nor other sign of severe inflammation. The right heart was dilated, the left ventricle strongly contracted. In two injections a third guinea pig, a female of 400 grams weight, received under the skin of the abdomen 0.1 gram of penicillic acid neutralized with sodium carbonate and dissolved in 1.5 cubic centimeters of normal saline solution. As soon as returned to the cage it began to feed, but an hour later was quiet and not very responsive to stimuli. It remained in this condition for an hour longer, when slight dyspnoea and signs of weakness appeared. An hour later the legs were weak, for the abdomen was allowed to rest on the ground. It still responded to stimuli, however, and did not remain on its back when turned over. Half an hour later its head was also resting on the ground. At the end of the fourth hour the weakness was so great it fell over on its side from time to time, but was able to right itself. Four and a half hours after the injection the animal sank over on its side and died without struggling. The autopsy showed that one of the injections had been made into the region of the functioning mammary gland. There was at this place a hemorrhagic effusion about an inch in diameter. There was a little serous exudation. The site of the other injection showed merely a little serous exudation. The animal was in an early state of pregnancy. Nothing else significant could be found.

Twelve milligrams of penicillic acid were dissolved in 1 cubic centimeter of normal saline solution by neutralizing with sodium carbonate. This was injected into the dorsal lymph sac of a frog of 45 grams weight. Though the frog was watched for 6 hours no symptoms were observed. Nevertheless, the following morning the animal was dead. The only thing noted on autopsy was that the heart was in systole.

A second frog of 35 grams weight received into the dorsal lymph sac 30 milligrams of penicillic acid dissolved with sodium carbonate. He soon began to get weak, without any other marked symptoms, and in 45 minutes had ceased breathing and was quite unresponsive. The body was at once opened. The auricles were still beating vigorously, but the ventricle was quiet in complete systole. It exhibited, only occasionally, slight fibrillation in the neighborhood of the auriculo-ventricular junction. This soon ceased, and 10 minutes later the auricles ceased pulsating.

Penicillic acid is also toxic to tadpoles. In a solution of 1 to 5,000 the animals seemed uncomfortable and restless as compared with the controls. There seemed to be considerable irritation, for the water became clouded with secreted mucus. At the end of 24 hours the animals were still in good condition and, when transferred to the aquarium, continued to live. In a solution of 1 to 2,000 similar

phenomena were observed, but after an hour there were occasional convulsive lashing movements. In the third hour the animals seemed to get weaker and the respiration became weak and shallow. At the end of 4 hours the animals no longer responded to stimuli, the respiration had almost ceased, and the animals did not recover when placed in the aquarium. In a solution of 1 to 1,000 the irritation and the lashing movements were more pronounced. For 2 hours there were fairly vigorous responses to stimuli; in 3 hours the animals were dead. The toxic effect was not observed when the tadpoles were placed in solutions of the neutral sodium salt. There was very little irritation, and they survived in solutions as strong as 1 to 1,000. For tadpoles the acidity of penicillic acid seems to be the chief factor in the toxic action, for in solutions of sulphuric and hydrochloric acid of a strength of 1 to 1,000 the animals were killed in 18 minutes. Moreover, in $n/200$ sulphuric acid, which has an acidity equivalent to that of a 1 to 1,000 solution of penicillic acid, the tadpoles died in an hour. These observations do not militate against the toxicity of penicillic acid, for it is probable that it is not to any considerable extent absorbed, because only minute traces, as has been shown, can be extracted from water by ether or by oil. The partition coefficient is too much in favor of water, and Overton¹ has shown that substances like these enter the organism very slowly. All these factors are still more effective in the case of solutions of the salt, which is quite insoluble in oils and most organic solvents. This is true in many other cases where the free acid is itself toxic aside from its acidity, but the salt quite harmless. Thus, Clark,² in whose paper the older literature is cited, states that the toxicity of acetic acid to *Penicillium* and certain other molds is due almost entirely to the un-ionized molecule CH_3COOH . Recently this fact has been rediscovered by Reichel.³ It was found in this investigation that even in neutralized solutions of salicylic acid of 1 to 1,000 tadpoles are unaffected. Finally Gosio and Ferrati⁴ state that neutralization of the toxic extracts prepared from their *Penicillium* cultures renders them much less toxic.

From all these data it appears that the toxicity of penicillic acid is of the same general magnitude as that of some of the phenols and phenol acids. According to Duplay and Maurice Cazin⁵ the lethal dose of phenol for mice is 0.296 gram per kilogram. This is nearly as large

¹ Overton, E. Studien über die Narkose, zugleich ein Beitrag zur allgemeinen Pharmakologie, Jena, 1901, 196 p.

² Clark, J. F. On the toxic effect of deleterious agents on the germination and development of certain filamentous fungi. Botanical Gazette, v. 28, p. 319, 1909.

³ Reichel, J. Ueber das Verhalten von *Penicillium* gegenüber der Essigsäure und ihren Salzen. Biochemische Zeitschrift, Bd. 20, p. 152-159, 1911.

⁴ Gosio, B., and Ferrati, E. Sull'azione fisiologica del veleno del mais invaso da alcuni funghi. Rivista d'Igiene e Sanità Pubblica, ann. 7, p. 981-981, 1896.

⁵ Duplay, Simon, and Cazin, Maurice. De l'action de l'acide phénique sur les animaux. Comptes Rendus de l'Académie des Sciences [Paris], t. 112, p. 627-630, 1891.

as the lethal dose of penicillic acid. For guinea pigs and rabbits the lethal dose of phenol is about twice as much. For guinea pigs the lethal dose of penicillic acid seems to be smaller.

The data of Duplay and Cazin agree quite well with the findings of Paul Binet, who determined the lethal dose for rats at 0.5 to 0.6 gram and for guinea pigs at 0.55 gram per kilogram.¹ Gosio and Ferrati² state that 5 to 10 milligrams of phenol or resorcin and 15 milligrams of salicylic acid subcutaneously are fatal to mice.

Granting that penicillic acid is related to lichen acids, it becomes a matter of interest to note that certain lichen acids have been found toxic. Kobert³ has found that vulpinic acid, a yellow substance found in *Evernia vulpina*, *Xantoria parietina*, and some other lichens, is a protoplasmic poison. He found both vulpinic and pinastric acid very toxic to frogs, and vulpinic and pinastric acids toxic to higher animals, while chrysophyscin is harmless. Zopf⁴ found none of them except vulpinic acid injurious to orthoptera, arachnids, or helix. He does not think the lichen acids protect the lichen from attacks by animals, a view previously expressed by Bachmann⁵ and Zukal.⁶ Stahl,⁷ however, believes that Zopf is only partly right.

Penicillic acid was found to resemble the crystalline substance of Gosio and the lichen acid, vulpinic acid, studied by Kobert,⁸ in having some antiseptic power, as shown by its action on pure cultures of baker's yeast and of *Bacillus coli*. Yeast was chosen because it flourishes when the reaction is acid. *B. coli* was selected because it forms acid from sugar and is not harmed by considerable variations of the environment. The culture was kindly furnished by Dr. Rogers, of the Dairy Division of the Bureau of Animal Industry, being No. 22 f. g. of his collection. It had been isolated originally in the Hygienic Laboratory of the Public Health and Marine-Hospital Service.

Yeast.—Six flasks, provided with a trap containing sulphuric acid to prevent moisture losses, received each 25 cubic centimeters of sterile Raulin's medium. Three received in addition enough crystalline penicillic acid to make the concentration 1 to 1,000. All

¹ Binet, Paul. Toxicologie comparée des phénols. *Revue Médicale de la Suisse Romande*, ann. 15, p. 567, 631, 1895.

Prevost, and Binet, Paul. *Travaux du Laboratoire de Thérap.*, Genf, 1896, p. 143. Cited in Fränkel, Sigmund, *Die Arzneimittel-Synthese*, Aufl. 2, Berlin, 1906, p. 55.

² Gosio, B., and Ferrati, E. *Op. cit.*

³ Kobert, R. Über Giftstoffe der Flechten. *Sitzungsberichte der Naturforscher-Gesellschaft*, Dorpat, Bd. 10, p. 165, 1892.

⁴ Zopf, W. Zur biologischen Bedeutung der Flechtensäuren. *Biologisches Centralblatt*, Bd. 16, p. 592-610, 1896.

⁵ Bachmann, E. Ueber nicht-krystallisierte Flechtenstoffe, ein Beitrag zur Chemie und Anatomie der Flechten. *Jahrbücher für Wissenschaftliche Botanik*, Bd. 21, p. 17, 1890.

⁶ Zukal, H. Morphologische und biologische Untersuchungen über die Flechten. *Sitzungsberichte der Mathematisch-Naturwissenschaftliche Classe der Kaiserlichen Akademie der Wissenschaften (Wien)*, Abt. 1, Bd. 104, p. 529-574, 1303-1395, 3 pl., 1895.

⁷ Stahl, Ernst. Die Schutzmittel der Flechten gegen Tierfraß. *Festschrift zum Siebzigsten Geburtstage von Ernst Haeckel*, Jena, 1904, p. 357. (*Denschriften der Medizinisch-Naturwissenschaftlichen Gesellschaft zu Jena*, Bd. 11.)

⁸ Kobert, R. *Op. cit.*

six were then inoculated with equal quantities of a suspension of the yeast and weighed. At intervals a pair of these flasks was heated to boiling and dry air drawn through them. They were cooled and weighed. The loss represents chiefly carbonic acid. The experiment was repeated, using a concentration of penicillic acid of 1 to 500. The results obtained are shown in Table III.

TABLE III.—Loss in weight of flasks of Raulin's medium treated with various quantities of penicillic acid and inoculated with yeast.

Time.	Loss in weight (grams) of flasks inoculated with yeast.			
	Proportion of penicillic acid 1 to 1,000.	Control (untreated).	Proportion of penicillic acid 1 to 500.	Control (untreated).
First day.....	0.4507	0.4587	0.3117	0.3506
Second day.....	.4520	.5453	.3535	.5308
Third day.....	.5293	.5720	.5550	.5755

In the control flasks no sugar was present after the third day. It was impossible to test the others because of the presence of penicillic acid, which is not destroyed by yeast but may be recovered almost quantitatively.

While these experiments do not disclose a powerful antifermentative action, still in both some decided effect is indisputable. While the yeast cells were not killed, there is an unmistakable retardation in the rate of fermentation. As far as could be judged by the naked eye, the multiplication of the cells was partly inhibited. At the end of the experiments there seemed to be much more yeast in the control flasks than in those containing penicillic acid. Whether the gross appearance corresponds to the facts will have to be determined by cell counts. It is not likely that these effects are due to the slight increase in acidity.

Bacillus coli.—For the culture medium 1 per cent acid bouillon was used. Series of test tubes were charged with 8 cubic centimeters. To the control tubes 1 cubic centimeter of normal salt solution was added. To the other tubes 1 cubic centimeter of a neutral solution of the sodium salt of penicillic acid was added of such a strength that the final concentration was 1 to 500. Both sets of tubes were sterilized for 20 minutes on three successive days in an Arnold sterilizer. A very dilute suspension of active bacteria was prepared and 1 cubic centimeter measured into each tube. The tubes were then incubated for 20 hours. When examined it was found that in the tubes containing penicillic acid there was very slight growth, whereas in the control tubes growth was abundant. The difference was so apparent that it was unnecessary to pour plates. As the neutral sodium salt

was used in this experiment there was no increased acidity, an objection which might be urged against the yeast experiments.

These experiments show that penicillic acid exerts some, though weak, antifermentative action. Stahl¹ has pointed out that the antiseptic power of vulpinic acid may be of considerable use to the lichen *Evernia vulpina* in protecting it from micro-organisms. One might advance a similar hypothesis for the secretion of penicillic acid. While it is likely that excretory products of one kind or another have this effect, their usefulness must be regarded as purely accidental and secondary, though it is not impossible that they play a part in selection. The theory that the formation of alcohol in the course of fermentation is for the purpose of suppressing competitors² must in this form be condemned.³ One might as well maintain that the formation of carbonic acid is for the purpose of furnishing the yeast cell with a means of locomotion or for the purpose of creating the optimum acidity for the action of invertase.⁴ It is true that alcohol and carbonic acid do these things for the yeast cell, but the phenomena are merely concomitant. The yeast experiments given above may indicate that penicillic acid has such a secondary effect, particularly when the oxygen supply to the organism is insufficient.

These observations on the antifermentative action of penicillic acid may furnish an explanation of the observation of Nikitinsky⁵ that yeast will not grow on a medium on which *Penicillium* has been sown one or two days before, and vice versa. This is not due to the exhaustion of the medium, for replacing the sugar consumed does not alter the results. On the whole, Nikitinsky is inclined to regard the acids formed by the first organism as the agent inhibiting the growth of the second. He draws this conclusion because acids are the only inhibiting substances known to be formed. The discovery of penicillic acid renders it possible that some of these inhibitions are due to the formation of specific substances. They may be very generally formed, for Nikitinsky found the same inhibiting effect with other pairs of organisms than yeast and *Penicillium*.

¹ Stahl, E. Op. cit., p. 374.

² Wortmann, Julius. Tätigkeit der Station in Bezug auf die Untersuchung und Behandlung kranker Weine. Bericht der Königl. Lehranstalt für Wein-, Obst-, und Gartenbau zu Geisenheim, p. 136, 1902.

Delbrück, M. Der physiologische Zustand der Zelle und seine Bedeutung für die Technologie der Gärungsgewerbe. Wochenschrift für Brauerei, Jahrg. 23, p. 513-516, 1906.

— and Schönfeld, F. System der natürlichen Hefereinsucht, Berlin, 1903, p. 10.

Jost, Ludwig. Vorlesungen über Pflanzenphysiologie, Jena, 1904, p. 258.

Klenitz-Gerloff, Felix. Bakterien und Hefen, etc., Berlin, 1904, p. 35.

³ Bierberg, W. Die biologisch-ökologische Theorie der Gärung. Centralblatt für Bakteriologie, [etc.], Abt. 2, Bd. 26, p. 187-189, 1910.

— Alkohol- und Essigsäuretoleranz der Bakterien und die Wortmannsche biologische Gärungstheorie. Idem, Abt. 2, Bd. 24, p. 452-435, 1909.

⁴ Hudson, Dr. C. B. Personal communication.

⁵ Nikitinsky, J. Ueber die Beeinflussung der Entwicklung einiger Schimmelpilze durch ihre Stoffwechselprodukte. Jahrbücher für Wissenschaftliche Botanik, Bd. 40, p. 66, 1904.

It is not possible, however, to reach any definite opinion concerning his experiments, because they are complicated by the fact that he does not state how the medium was sterilized after the growth of the first organism. If sterilized with heat, it is possible that inhibiting substances were injured or volatilized.

A detailed study of the pharmacological action of penicillic acid on warm-blooded animals was not made, because to procure enough material would have unduly delayed publication. Such a study is reserved for a future paper. A single experiment indicating the effect on the blood pressure was performed, using a 6-kilogram dog in morphine-ether anaesthesia. The blood pressure in the carotid was recorded upon a kymograph in the usual way. In the course of 12 minutes 23 cubic centimeters of a 2 per cent solution of penicillic acid in physiological salt solution were introduced into the saphenous vein. Somewhat before the end of the injection the blood pressure began to fall and ultimately reached 65 per cent of the original value. Then it gradually recovered, until at the end of 10 minutes it had returned to its original value. During the stage of depression the heartbeat was slightly more rapid, but it also recovered.

It is a matter of considerable interest to compare the toxicity of penicillic acid with that of the extracts obtained by various investigators from various fungi. The only experiments strictly comparable with those on penicillic acid just recorded are those with Gosio's pure substance, in which no toxic effect was obtained. All other recorded experiments deal with impure mixtures. The extracts obtained by Gosio, Di Pietro, Sturli, and others were far more toxic than penicillic acid. This is particularly true of Di Pietro's "glucosid." One and a half milligrams of his impure extract caused within a quarter of an hour intense acute symptoms in a guinea pig of 300 grams.

Toxic preparations were obtained by Gosio's student, Paladino-Blandini,¹ from the toxic variety of *Penicillium glaucum* used by Gosio ("Var. ipertossico, Gosio"), from *Oospora*, *Rhizopus*, and *Aspergillus*. One does not, on carefully examining his protocols, get the impression that any of the organisms were very poisonous. This may have been due to the fact that his culture media were often alkaline or that he concentrated the media on the steam bath before testing for toxicity. If any of the organisms produced substances like penicillic acid these might have been destroyed either by the alkalinity or by the heating, for, as has been shown, penicillic acid is unstable under these conditions. Paladino-Blandini makes this point himself for the poison of *P. glaucum*, which he found to be ther-

¹ Paladino-Blandini, A. Tossici di Miceti. Archivio di Farmacologia Sperimentale e Scienze Affini, v. 5, p. 606-644, 1908.

molabile and volatile. Obviously in these experiments he was not dealing with *P. puberulum*.

Paladino-Blandini used these observations to explain some of the results of Ceni,¹ who claimed that the production of toxic or phenolic substances by various molds fluctuated with the season, being greatest in the spring and fall. Since Ceni always injected inspissated culture fluid or extracts, Paladino-Blandini suggested that the heating probably destroyed or volatilized the toxic substances, so that conditions were not constant. Di Pietro, too, was unable to confirm Ceni, for his organism was equally toxic all the year round. In the present investigation these results were checked by determining the amount of penicillic acid formed under like conditions at different times of the year. About the same yield of this acid was obtained in every month of the year. Against these observations must be set the statements of Otto² that extracts of *Aspergillus* cultures are toxic from April to October.

PHYSIOLOGICAL STUDIES OF *PENICILLIUM PUBERULUM*.

In order to obtain, if possible, better yields of penicillic acid, the organism was grown upon Raulin's medium, variously modified. The other conditions of growth remained the same as those previously used to procure penicillic acid.

The culture media employed may be classed in two groups: Those in which some component of Raulin's medium was replaced by an equivalent amount of another substance, and those in which some substance was added to Raulin's medium. The first group comprised the following substitutions:

Succinic acid for tartaric.

Sodium acetate for tartaric acid.

One and a half per cent ethyl alcohol for cane sugar and tartaric acid.

Leucin instead of nitric acid and ammonia. The amount of leucin was calculated to contain an equivalent amount of nitrogen. The leucin was pure and prepared by hydrolyzing plant protein, esterifying the resulting amino acids, subjecting them to fractional distillation, and saponifying.³

Tyrosin instead of nitric acid and ammonia. The tyrosin was prepared in the usual way by hydrolyzing horn with strong mineral acids.

One-tenth per cent amyl alcohol for cane sugar and tartaric acid.

Witte's peptone for nitric acid and ammonia.

The second group comprised the following:

Addition of 0.05 per cent amyl alcohol to Raulin's medium.

Addition of 0.01 per cent amyl alcohol to Raulin's medium.

Addition of 0.1 per cent amyl alcohol to Raulin's medium.

Most of the results have been collected in Table IV.

¹ Ceni, Carlo. Le proprietà tossiche di alcuni funghi in rapporto colle stagioni e col ciclo annuale dell'endemia pellagrosa. Comunicazione preliminare. Rivista Pellagologica Italiana, v. 4, p. 89.

² Otto, M. Ueber die Giftwirkungen einiger Stämme von *Aspergillus fumigatus* und *Penicillium glaucum* nebst einigen Bemerkungen über Pellagra. Zeitschrift für Klinische Medizin, Bd. 59, p. 332-333, 1906.

³ This preparation was very kindly furnished by Dr. I. K. Phelps, of the Bureau of Chemistry.

TABLE IV.—Observations on the physiology of *Penicillium puberulum*.

Medium.	Age of culture. ¹	Appearance of spores. ²	Color of medium.	Weight of mycelium.	Volatile products.	Ethyl alcohol.	Addity of 10 c. c. of medium.	Penicillio acid.	Remarks.
Baslin's medium.	Days. 30-40	6th to 10th.	Brown, dark, transparent.	Grams. 8. Some already auto-lysed.	No aldehyde; traces of acid; none with insoluble Ag. salts.	0.1 per cent.	1.1 c. c. n/10 alkali.	About 0.2 gram in 700 c. c. Present.	Spore formation much delayed; culture medium pale.
Succinic acid.	31	About the 6th.	do.	4.76.	Traces of aldehyde and acetic acid.	Present.	Not determined.	Absent.	
Sodium acetate.	31	10th traces, 15th abundant.	Darkening delayed.	Not weighed.	Not studied.	Not studied.	Alkaline.	Absent.	
Ethyl alcohol 1.5 per cent.	70	About the 60th	Pale.	Very slight.	do.	do.	Not studied.	Not tested.	Spores did not germinate; after inoculation with mycelium very slow and scanty growth. A trace of an alkaloid, soluble in chloroform, present. Very abundant spore formation.
Witte's peptone.	26	9th.	Very dark.	Not weighed.	Absent.	Absent.	Alkaline.	Trace.	Rapid, but very flat, thin, and delicate growth; strong musty odor.
Leucine.	33	8th.	Light brown.	7.7.	No amyl alcohol; volatile acid-reducing Ag. present.	Present.	0.6 c. c. n/10 alkali.	Absent.	
Tyrosine.	38	8th.	do.	4.25.	No tyrosine or tyrosol; volatile acid-reducing Ag. present.	Not studied.	2.7 c. c. n/10 alkali.	do.	
Amyl alcohol: 0.1 per cent.		6th to 10th.	As in plain Baslin's medium.	Not weighed.	Amyl alcohol present.	Present.	Acid.	Present.	No growth. Growth good.
do.		do.	do.	do.	do.	do.	do.	do.	Do.
0.01 per cent.									Almost no growth.
0.1 per cent.									

¹ The age refers to the interval between inoculation and chemical examination.

² The first tinge of green coloration visible to the naked eye was taken as a sign of spore formation. Many colorless or a few colored spores may have been formed sooner.

³ Hesse's (Botanical Gazette, v. 45, p. 170, 1908) reported abundant spore formation with potassium acetate as the only source of carbon.

A number of other facts were observed which have not been incorporated in the table. Thus it was found that in the cultures on Raulin's medium the tartaric acid soon disappeared. At least none could be isolated as the acid potassium salt. Indeed, the tartaric acid seems to be attacked at the beginning more rapidly than the sugar. Pfeffer¹ has reported analogous observations upon *Aspergillus*. Reichel² found very recently that *Penicillium* when grown in the presence of acetic acid begins to destroy the acid until the unfavorable acidity is reduced. A concentration of acetic acid equivalent to the tartaric acid of Raulin's medium was found to inhibit the development of *Penicillium puberulum*. That is why in one of the experiments of Table IV sodium acetate was used. There seems to be a general tendency for molds to reduce the acidity of a very acid medium. This may be done by destroying the acid, or, if the acid can not be attacked, by neutralizing it with ammonia when this can be formed by deamidization.³ At any rate in the present instance the sugar disappeared more slowly than the tartaric acid. By the end of the fourth week, however, the medium was no longer optically active⁴ or fermentable. Because penicillic acid renders the solution antiseptic the fermentation test is not in this instance reliable. Nevertheless the medium reduces Fehling's solution, 25 cubic centimeters yielding 78.1 milligrams of cuprous oxid.⁵ The reduction is caused by penicillic acid.

Alcohol was determined by taking the specific gravity of the rectified distillate. The cultures contained 0.1 per cent as early as the end of the first week. The low concentration of alcohol found might not be the result of a scanty alcohol formation, but of the further oxidation of the alcohol formed, since alcohol is a good food for *Penicillium*.⁶ Indeed, it has been said that "*P. glaucum*" does not produce alcohol at all.⁷ Dox states that alcohol of a concentration not over 0.1 per cent is produced only when the air supply is insufficient.⁸ All cultures of *Penicillium puberulum* tested contained alcohol, even those grown in the flat bottles above described, in which the aeration was certainly good.

¹ Pfeffer, W. Ueber die Election organischer Nährstoffe. *Jahrbücher für Wissenschaftliche Botanik*, Bd. 28, p. 205-268, 1896.

² Reichel, J. Ueber das Verhalten von *Penicillium* gegenüber der Essigsäure und ihren Salzen. *Biochemische Zeitschrift*, Bd. 30, p. 152-159, 1911.

³ Butkewitsch, Wl. Umwandlung der Eiweissstoffe durch die niederen Pilze im Zusammenhange mit einigen Bedingungen ihrer Entwicklung. *Jahrbücher für Wissenschaftliche Botanik*, Bd. 38, p. 198, 1902.

⁴ The determinations were very kindly made by Dr. C. S. Hudson, of the Bureau of Chemistry.

⁵ This determination was very kindly made by Dr. H. Hasselbring, of the Bureau of Plant Industry.

⁶ Hasselbring, Heinrich. The carbon assimilation of *Penicillium*. *Botanical Gazette*, v. 45, p. 170-193, 1908.

⁷ Brefeld, Oscar. Ueber Gährung. III. Vorkommen und Verbreitung der Alkoholgährung im Pflanzenreiche. *Landwirthschaftliche Jahrbücher*, Bd. 5, p. 315, 1876.

⁸ Dox, A. W. The intracellular enzymes of *Penicillium* and *Aspergillus*, with special reference to those of *Penicillium camemberti*. - U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 120, p. 33, 1910.

No glycerin could be detected in the culture fluid when 200 cubic centimeters, rendered weakly alkaline with sodium carbonate, were concentrated to a sirup, the sirup extracted with alcohol, and the alcoholic extract after evaporation tested with the borax bead.

Though the Raulin medium cultures remained distinctly acid to litmus, no nonvolatile acid other than penicillic acid could be extracted with sulphuric ether, petroleum ether, or acetic ether, even after acidifying with phosphoric acid. No insoluble lead, copper, calcium, barium, or zinc salt could be obtained. Great care was taken to detect oxalic acid, but in young cultures none could be found. Even in old cultures none could be detected by the ordinary method of extraction with ether. A small amount was isolated in the following manner: Seven hundred cubic centimeters of culture medium about two months old were concentrated to a sirup, acidified with phosphoric acid, and mixed with clean sand and plaster of Paris. When the plaster had set, the mass was ground and extracted with ether in a Soxhlet extractor. Oxalic acid, identified by its melting point, crystallized from the extract, which also contained other material, as shown by the evolution of gas and the odor of nitrous oxid. Apparently some nitric acid passed from the medium into the extract and there caused decomposition. The extract contained a substance soluble in chloroform and giving a bright-green color with ferric chlorid. An alkaline solution of penicillic acid when concentrated to a sirup does not yield oxalic acid, but it does give a green color with ferric chlorid. Fumaric acid was absent. As already indicated, the culture medium contained unidentified substances. This was further shown by the fact that by the method of Griess, using sodium nitrite, sulphanilic acid, and acetic acid, an azo dye of a beautiful carmine color was produced. This reaction was obtained by Raciborski¹ with a number of fungi.

Only very small quantities of volatile material other than alcohol were detected in the culture medium. For the purposes of this examination a culture medium from which the penicillic acid had been removed as thoroughly as possible with chloroform to avoid obtaining its decomposition products, was used. The medium was then distilled and the distillate extracted, first with chloroform and then with ether. The residue from the chloroform consisted of a few small white crystals with a melting point of 112° C. The residue from the ether consisted of a few fine hairlike crystals. None of the crystals gave the ferric-chlorid reaction. Distillation of this liquid with mineral acid yielded no other products. Distillation with

¹ Raciborski, M. Über die Assimilation der Stickstoffverbindungen durch Pilze. Bulletin International de l'Académie des Sciences de Cracovie. Classe des Sciences Mathématiques et Naturelles, ann. 1906. p. 733-770. 1907.

alkali yielded a few white crystals obtained by extracting the distillate with ether.

All these experiments refer to the unmodified Raulin's medium. The mycelium was also studied. From mycelium of varying age grown under different conditions no toxic material could be extracted with boiling alcohol. An oily, waxy residue remained after the alcohol was removed on the steam bath. When this residue was extracted with water and the extract injected subcutaneously into mice no serious toxic effects were observed.

Mannitol has long been known as a constituent of *Penicillium*.¹ Trehalose and trehalum, or substances resembling them, have also been described. It is possible that in fungi some investigators may have mistaken trehalum for starch or glycogen.² Cramer³ found that by treating the spores of *Penicillium* with boiling water no carbohydrate material precipitable by alcohol passed into the extract. When, however, the spores were exhausted with ether before the extraction, a carbohydrate was obtained giving a deep blue color with iodine. This carbohydrate, Cramer thought, resembled hemi-cellulose, but it may have been similar to trehalum. Moreover, a direct relationship between mannitol, trehalose, and trehalum has been demonstrated, trehalose being formed only at certain stages of growth, while later only mannitol occurs.⁴

Mannitol was readily detected in the mycelium of *Penicillium puberulum* by extracting the mycelium dried in air with boiling alcohol. On cooling, sweet, fine, white, silky needles separated, soluble in water and alcohol, insoluble in chloroform, and with a melting point of 162° to 163° C., uncorrected. Cholesterol reactions were negative. They did not reduce Fehling's solution, though they did so after oxidation with nitric acid. They rotated polarized light slightly to the left.

In the mycelium dried in air neither trehalose nor trehalum could be detected. When fresh mycelium was immersed in boiling alcohol, as soon as removed from the culture flask and the boiling extract filtered, no trehalose separated on cooling. This extracted mycelium, boiled with water and filtered hot, gave, on cooling, a small quantity of gummy material which iodine colored intensely violet and which was not easily inverted by hot dilute hydrochloric acid. This substance is plainly trehalum, in no way mistakable for glycogen or the more readily soluble and easily inverted starch.

¹ Zopf, Wilhelm. Die Pilze, Breslau, 1890, p. 125.

² Lippmann, E. O. von. Die Chemie der Zuckerarten, Aufl. 3, Halbbd. 2, Braunschweig, 1904, p. 1429-1430.

³ Cramer, E. Die Zusammensetzung der Sporen von *Penicillium glaucum* und ihre Beziehung zu der Widerstandsfähigkeit derselben gegen äussere Einflüsse. Archiv für Hygiene, Bd. 20, p. 197-210, 1894.

⁴ Lippmann, E. O. von. Op. cit., p. 1427.

Both the culture fluid and the mycelium were examined for oxidizing enzymes. The former contains an abundance of catalase, though no oxidase detectable by guajac, aloin, or benzidin. A very faint peroxidase reaction was found, due perhaps to the presence of chlorids.¹ The statement of Loew² that filtered *Penicillium glaucum* cultures contain only catalase is therefore amply confirmed. Fresh and air-dry mycelia were ground in a mortar with distilled water and allowed to digest at room temperature for several hours. The extract, filtered through paper, contained far more catalase than the culture medium, but neither oxidase nor peroxidase could be detected by the color tests. In performing these tests great care was taken to vary the reaction, for this has been shown to influence these tests greatly.³

The mycelium was then tested for oxidizing power by the method of oxygen absorption as developed in this laboratory by Dr. H. H. Bunzel.⁴ The air-dry mycelium was ground and the dry powder obtained used directly in the oxidase apparatus in the presence of pyrogallol and of tyrosin. No oxygen absorption was observed. To make certain that neither the drying nor the acid of the medium was accountable for the negative results, the organism was grown on a medium containing monosodium phosphate and disodium phosphate, which, as shown by Henderson and Webster,⁵ remains neutral. This medium was Raulin's solution, to which was added 5 per cent of a mixture of two parts Na_2HPO_4 and one part NaH_2PO_4 . On this medium few spores developed in 10 days. The mycelium remained colorless. The medium contained alcohol and only traces of penicillic acid. Ten grams of perfectly fresh mycelium of 12 days' growth were ground with clean sand and then transferred to the absorption flask, together with 4 cubic centimeters of 10 per cent pyrogallol. This concentration of pyrogallol was selected because of its antiseptic action. Under these conditions no oxygen absorption was observed for more than an hour. Absorption then gradually began. This phenomenon is still under investigation.

Some of the results obtained with the variously modified Raulin's medium require further comment.

In the distillate from the succinic-acid culture aldehyde was detected by the power to reduce ammoniacal silver, and acetic acid by the formation of the ethyl ester with its characteristic odor.

¹ Alsberg, C. L. Beiträge zur Kenntnis der Guajak-Reaktion. Archiv für Experimentelle Pathologie und Pharmakologie, Festschrift Schmiedeberg, Supplementband, p. 39, 1908.

² Loew, Oscar. Catalase, a new enzym of general occurrence, with special reference to the tobacco plant. U. S. Department of Agriculture, Report 68, 1901.

³ Alsberg, C. L. Op. cit.

⁴ Bunzel, H. H. The measurement of the oxidase content of plant juices. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 238, 1912.

⁵ Henderson, L. J., and Webster, H. B. The preservation of neutrality in culture media with the aid of phosphates. Journal of Medical Research, v. 16, p. 1-5, 1907.

The observation made on the 1.5 per cent ethyl-alcohol culture that mycelium failed to develop from spores, whereas inoculation with pieces of mycelium resulted in growth, is in harmony with the statement of Duclaux¹ that while alcohol restrains or arrests the germination of mold spores it is utilized almost as abundantly as sugar by the adult plant. These observations were confirmed by Clark.² The mycelium of *Penicillium puberulum* developed very slowly from mycelium inoculation on 1.5 per cent alcohol. In the course of a few weeks a delicate, thin, green growth spread over the surface of the medium. Except for the green color it had the appearance of the scum of lead oxid that forms on the surface of molten lead exposed to the air.

The peptone cultures turned exceedingly dark. When the alkaline medium was extracted with chloroform, the residue of the extract consisted of a little oil which was for the greater part soluble in acid. The acid solution gave a decided precipitate with Meyer's reagent for alkaloids. The small quantity available was not toxic to mice. When the medium was acidified before extraction a little nontoxic oil passed into the chloroform. By extracting with warm water no penicillic acid was obtained. However, on long standing with ferric chlorid the extract developed a faint rose color.

The purpose of the leucin and tyrosin cultures was to ascertain whether *Penicillium puberulum* is able to deamidize amino acids as yeast does. If this were the case amyl alcohol would have been found in leucin cultures and tyrosol or tyrol in tyrosin cultures.³ Amyl alcohol was sought by the method of Beckmann,⁴ and tyrol and tyrosol by the method of Ehrlich.⁵ Raciborski⁶ first observed differences in the manner in which different molds decompose tyrosin. He found that *P. glaucum* grown on tyrosin agar produced a substance reducing silver. Since both leucin and tyrosin are destroyed by *P. puberulum*, it is evident that either their decomposition differs from that to which these amino acids are subjected by yeast, or else amyl alcohol, tyrol, and tyrosol are merely intermediary products.

¹ Duclaux, E. Sur la nutrition intracellulaire. Annales de l'Institut Pasteur, ann. 3, p. 97-112, 1899.

² Clark, J. F. On the toxic effect of deleterious agents on the germination and development of certain filamentous fungi. Botanical Gazette, v. 23, p. 385, 1899.

³ After the completion of these experiments, Ehrlich and Jacobsen reported that *Penicillium glaucum* is able to decompose amino acids to simpler compounds of lower molecular weights. Still more recently, Herzog and Saladin published similar results. See Ehrlich, Felix, and Jacobsen, K. A., Über die Umwandlung von Aminosäuren in Oxyssäuren durch Schimmelpilze. Berichte der Deutschen Chemischen Gesellschaft, Jahrg. 44, p. 888-897, 1911; Herzog, R. O., and Saladin, O., Über das Verhalten einiger Pilze gegen Aminosäuren, Zeitschrift für Physiologische Chemie, Bd. 73, p. 302-307, 1911.

⁴ Beckmann, Ernst. Zur Bestimmung des Fuselölgehaltes alkoholischer Flüssigkeiten. Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, Bd. 10, p. 143-152, 1905.

⁵ Ehrlich, Felix. Über die Vergärung des Tyrosins zu p -oxyphenyl-äthylalkohol (Tyrosol). Berichte der Deutschen Chemischen Gesellschaft, Jahrg. 44, p. 139-146, 1911.

⁶ Raciborski, M. Über die Assimilation der Stickstoffverbindungen durch Pilze. Bulletin International de l'Académie des Sciences de Cracovie. Classe des Sciences Mathématiques et Naturelles, ann. 1906, p. 767. 1907.

That the latter is probably the case is indicated by the fact that penicillic acid is formed abundantly only under conditions of imperfect aeration. Perhaps under these conditions tyrosin and leucin would be less completely oxidized. It certainly is significant that yeast which grows anaerobically produces tyrosol or *p*-oxyphenyl alcohol from tyrosin, a substance which resembles penicillic acid in bitter, toxic,¹ and certain chemical properties. Another observation of Raciborski² suggests a different explanation of the results. He found that *Aspergillus niger* in a condition of carbon hunger decomposes tyrosin in a different way than when it is plentifully supplied with sugar. It is possible that since *P. puberulum* was allowed to grow more than a month it was, during the latter period of its growth, in a state of carbon starvation because all the sugar had been consumed.

The amyl-alcohol cultures were designed to learn whether this alcohol could be oxidized by *P. puberulum*. It was thought that in this way some indication might be given showing whether it was an intermediary product in the decomposition of leucin. Unfortunately, as inspection of Table IV shows, amyl alcohol is so poisonous that the question can not be definitely settled in this way. The percentage tolerated is so small that the quantity can not be determined with sufficient accuracy. It may, however, be stated that there is no evidence that amyl alcohol is oxidized by *P. puberulum*, since after several weeks' growth it had not disappeared from cultures containing as little as 0.05 per cent. In these cultures it was separated by the method of Beckmann, the characteristic odor being recognized in the final extract. These observations probably have little bearing on the question of the intermediary formation of amyl alcohol from leucin. As far as they indicate anything they are not in favor of it.

In both leucin and tyrosin cultures an appreciable amount of volatile acid was found, possibly formic acid, since the silver salt was rapidly reduced. Because of this property the acid from the leucin culture was not studied. That from the tyrosin culture formed a crystalline barium salt. The quantity was too small for analysis.

The tyrosin culture presented a number of peculiarities. While the musty odor of the growth on ordinary Raulin's medium was perceptible only when the mycelium was held close to the nose, that on tyrosin had a typical and extremely musty odor which permeated the room when the flask was opened. The odor of ordinary cultures became more perceptible when they were distilled, since the odoriferous

¹ Ehrlich, Felix. Über die chemischen Vorgänge des pflanzlichen Eiweissstoffwechsels und ihre Bedeutung für die alkoholische Gärung und andere pflanzenphysiologische Prozesse. Landwirthschaftliche Jahrbücher, Bd. 38, Ergänzungsbd. 5, p. 306-307, 1909.

² Raciborski, M. Op. cit., ann. 1906, p. 765. 1907.

principle seemed to accumulate in the distillate. Thom¹ observed that the production of odors varied greatly not merely from species to species, but also in some individual species according to the culture medium. It would be interesting to investigate whether in the present case the production of the odorous principle was actually dependent upon the presence of an aromatic compound or upon some other condition. Such factors as these may be involved in the production of the flavor of cheese.

The rate of growth was very much more rapid at first than in the controls, in spite of the fact that little more than half the tyrosin was consumed. Moreover, spore formation began before the fifth day and was very abundant. In less than a week the entire surface of the liquid was covered with mycelium uniformly green with spores. It was more delicate and less stiff and woody than that of the controls. It was smooth and even, and lay flat on the surface, whereas in the controls it was convoluted and twisted so that some of it was pushed below the surface, resulting in the formation of new mycelium above. In the tyrosin the growth, after the surface had once been covered, seemed less bulky, although the old mycelium was gradually overgrown with new mycelium.

Certain of the facts here recorded have some theoretical interest. This is particularly true of the peculiarities of growth of the tyrosin culture and of the absence of easily detectable oxidizing enzymes in all the cultures tested.

The peculiarities of the tyrosin culture which are of interest in this connection are the thinness of the mycelium and precocity of the spore formation. Tyrosin contains the aromatic ring. Perhaps a large amount of aromatic derivatives is required so that spore formation can not take place until the organism has had time to manufacture these aromatic compounds from the sugar and other straight-chain carbon compounds offered. When an assimilable aromatic compound is offered, this latent period is perhaps bridged over. Certainly, on the tyrosin the spore formation is at least as rapid as on corn-meal mush, which, in its proteins, contains an abundance of aromatic compounds. The importance of various amino acids for microbic growth has recently been brought out in studies on the cultivation of the leprosy bacillus.² Another explanation may, however, be based on the assumption that spore formation is rapid in an exhausted or unfavorable medium. That this is actually true is still an open question, though Tiraboschi³ presents

¹ Thom, Charles. Cultural studies of species of *Penicillium*. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 118, p. 90, 1910.

² Duval, C. W. Cultivation of the leprosy bacillus from the human tissues, with special reference to the amino acids as culture media. *Journal of Experimental Medicine*, v. 13, p. 365-373, 1911.

³ Tiraboschi, C. Studi sugli ifomiceti parassiti del granturco guasto. *Atti del Terzo Congresso Pellagologico Italiano*, Milano, 24-25-26 Settembre, 1906, p. 138. 1907.

evidence for this view. If this hypothesis be accepted it would be necessary to assume that tyrosin is an unfavorable source of nitrogen, either because of its chemical properties or because of its insolubility. That its chemical properties are the cause seems hardly likely, since leucin, which also contains amino nitrogen, gives such an abundant growth, although Raciborski¹ states that tyrosin is a much poorer source of nitrogen for *Aspergillus niger* than ammonia. That its insolubility is the cause is quite possible. Tyrosin is so little soluble that the amount in solution at any moment would be very much less than in the unmodified Raulin's medium, for most of the tyrosin contained in the culture had crystallized out on the bottom of the flask, at least 5 centimeters below the mycelium. Hence, it is possible that the rapid sporification was a sign of nitrogen starvation, which is the more likely, as the culture was very little handled or agitated. Under these conditions diffusion is very slow indeed, particularly for substances of great molecular weight like tyrosin. That diffusion does not keep pace with consumption of material is evident if any flask culture which has remained undisturbed for some days be examined. If such a culture be held between the eye and the light and gently rotated, convection currents can be seen near the mycelium, showing that the specific gravity of the liquid in immediate contact with the mycelium is very much less than that of the deeper layer. It may therefore be that after the first few days the mycelium was in relative nitrogen starvation. This hypothesis would account for the rapid initial and slow subsequent growth.

A perusal of the literature on the metabolism of the fungi shows that this question of the rate of diffusion has not received adequate attention. If the organism is grown on a thick layer of culture fluid the rate of diffusion of the dissolved substances is undoubtedly an important factor. A substance of small molecular weight will diffuse upward more rapidly to replace that consumed than one of great molecular weight. Thus the substance of small molecular weight might appear to be a better food relatively than it really is. The same logic applies to metabolic products. When these products are substances like alcohol, of light specific gravity, they will accumulate at the surface, particularly if the viscosity of the culture fluid is great, owing to the presence of much sugar or peptone. If, then, the alcohol concentration be determined for the whole fluid the values obtained may be spurious. Actually the mycelium may have been in contact with a much higher concentration of alcohol. This may be one of the reasons why the crop of mycelium for a given amount of sugar is said to be greater when the organism is grown on a thin

¹ Raciborski, M. Über die Assimilation der Stickstoffverbindungen durch Pilze. Bulletin International de l'Académie des Sciences de Cracovie. Classe des Sciences Mathématiques et Naturelles, ann. 1906, p. 764. 1907.

layer with great surface than when grown on a thick layer of culture fluid with smaller surface.¹ The largest yields were obtained in this way.

The absence of easily detectable oxidase is significant in connection with the discovery of Euler and Bolin that the oxidase of alfalfa (*Medicago sativa*) is a mixture of the calcium salts of simple oxyacids.² It is believed by some that many molds do not require calcium.³ It is tempting to imagine a connection between the absence of easily detectable oxidase, the observation of Euler and Bolin, and the absence of calcium.

GENERAL CONSIDERATIONS.

Since it has been definitely shown in the present paper that a distinct species of *Penicillium* produces a substance of moderate toxicity, the question very naturally arises, has it any pathological significance? At present it can only be said that it is too early to answer this question. All that can be done is to discuss the possibility and to indicate further work to be done.

In acute intoxications, alleged to be due to molds, penicillic acid alone can hardly be of significance. The lethal subcutaneous dose for mice, as has been shown, is about 0.3 gram per kilogram of body weight. Assuming the same susceptibility for the average man of about 70 kilos, the dangerous dose would probably be about 21 grams. Hence, an acute intoxication from penicillic acid would require that an inconceivably great quantity of moldy food be consumed in a single day. Even herbivorous animals could hardly eat enough moldy fodder in a day to be acutely affected by penicillic acid. It is quite out of the question that in the natural course of events penicillic acid is likely to produce acute intoxication.

However, the results of this investigation of *Penicillium puberulum* indicate the possibility of acute intoxication by moldy food. As already stated, the different species of *Penicillium* differ radically in their biochemical behavior. If there is so much difference in the ordinary products of metabolism, it is altogether likely that a series of toxic substances may be produced by different species. Some of these substances might very well be far more toxic than penicillic acid. Indeed, Italian investigators have shown this contingency to be very probable. Gosio, Di Pietro, and Sturli have obtained from pure cultures of *Penicillium* toxic extracts far more poisonous than

¹ Nikitinsky, J. Ueber die Beeinflussung der Entwicklung einiger Schimmelpilze durch ihre Stoffwechselprodukte. Jahrbücher für Wissenschaftliche Botanik, Bd. 40, p. 43, 1904.

Raciborski, M. Op. cit., p. 733-734.

² Euler, H., and Bolin, I. Über die chemische Zusammensetzung und die biologische Rolle einer Oxidase. Zeitschrift für Physikalische Chemie, Bd. 89, p. 187-202, 1909.

³ Loew, Oscar. Über die Giftwirkung von oxalsäuren Salzen und die physiologische Funktion des Calciums. Biochemische Zeitschrift, Bd. 38, p. 226-243, 1912.

Robert, Mlle. Influence du calcium sur le développement et la composition minérale de l'*Aspergillus niger*. Comptes Rendus de l'Académie des Sciences [Paris], t. 153, p. 1175-1177, 1911.

anything hitherto obtained in the new work herein recorded. Because none of these investigators have isolated the toxic principle in a state of purity their researches have not been given the serious consideration that is their due. It will be the task of this laboratory to extend these investigations to other species of *Penicillium* in the hope that other toxic substances, perhaps more active than penicillic acid, may be isolated.

In the matter of chronic intoxication the situation is quite different. Continued use of moldy food containing penicillic acid might produce symptoms. The quantity of badly spoiled corn-meal mush which a man would consume at a single meal might contain as much as 0.1 to 0.5 gram of penicillic acid. As this acid has a toxicity of the same order of magnitude as phenol, resorcin, or salicylic acid, and as such substances are believed by many to be undesirable as food preservatives, it seems reasonable to demand that great care be exercised in eliminating moldy corn from the diet. Owing to the difficulty of procuring material, it has not been possible to conduct long-continued feeding experiments. Therefore it is impossible to say whether penicillic acid has cumulative action. Should it prove to have such action chronic intoxication might be brought about by comparatively small doses. For this reason it is very desirable to learn the constitution of penicillic acid in order to be able to make it synthetically. This is the most promising way to obtain larger quantities of it.

While the finding of penicillic acid indicates that the relation of moldy corn to pellagra¹ deserves renewed attention, this discovery does not materially strengthen the maize theory of the etiology of pellagra. Penicillic acid itself is not sufficiently toxic. It is quite possible that penicillic acid or a closely related substance may have been responsible for the toxic effects following the administration of "pellagrozein," the poison obtained from spoiled maize, with which, according to the experiments of Lombroso,² the disease could be produced artificially. "Pellagrozein" itself Lombroso did not regard as anything but a mixture. He believed it contained two alkaloids, which accounted for the toxic action. Neither alkaloid has ever been obtained in a state of purity, so that it is impossible to form any definite opinion about them. Indeed, other investigators have not been able to find alkaloids at all in spoiled maize.³ It is quite

¹ Cf. Marie, A., Pellagra, authorized translation from the French, by C. H. Lavinder and J. W. Babcock, Columbia, S. C., 1910.

² Lombroso, Cesare, and Erba, Carlo. Sulle sostanze stricniche e narcotiche del mais guasto. Reale Istituto Lombardo, Rendiconti, s. 2, v. 9, p. 133-147, 1876.

³ Monselise, G. Ricerche chimico-tossicologiche intorno ad alcuni campioni di mais per la studio della pellagra, Mondovì, 1881, 58 p. (Cited by Gosio.)

Seimi, Antonio. Delle alterazioni alle quali soggiace il granturco (*Zea mays*) e specialmente di quello che ingenera la pellagra. Atti della R. Accademia dei Lincei, s. 3, Memorie della Classe di Scienze Fisiche, Matematiche e Naturali, v. 1, dispensa 2, p. 1099-1141, 1877.

Di Pietro, Melchiorre. Sui veleni di alcune muffe. Annali d'Igiene Sperimentale, v. 12 (n. s.), p. 314-365, 1902.

possible that these alkaloids were either normal constituents of maize or ptomainelike bases, as was pointed out by Pelloggio,¹ for the investigators who found alkaloids seem to have often allowed the maize to spoil to an extreme degree. In one case the maize was actually allowed to rot until it stank.² If the maize used contained either penicillic acid or some similar substance the method of preparation was such that these substances would have passed into the "pellagrozein," which is even less toxic than penicillic acid. The lethal subcutaneous dose varied from 1.5 grams per kilogram for frogs to 7 to 10 grams for cats.³ Hence, it is not impossible that "pellagrozein" contains substances of this type. Whatever evidence there is for the relation between "pellagrozein" and pellagra would apply equally well to penicillic acid. The discussion of this question lies beyond the scope of the present paper.

PENICILLIUM STOLONIFERUM.

In a former publication⁴ it was stated that most of the samples of spoiled American maize examined in this laboratory failed to give Gosio's⁵ phenol test with ferric chlorid. In this respect American spoiled maize seems to differ from that found in Italy, where the ferric-chlorid reaction is regarded as a reliable test for the deterioration of maize.⁶

Since the publication of the above-cited studies of the deterioration of maize the test has been improved in this laboratory so that in its new modification it is more delicate. The procedure as now conducted consists in extracting 50 grams of ground corn or meal in a stoppered flask, with sufficient chloroform to cover the mass. After two hours the chloroform extract is filtered off and concentrated to a bulk of 10 to 15 cubic centimeters. This concentrate is transferred to a small separatory funnel or test tube and covered with 5 cubic centimeters of water containing a trace of ferric chlorid. If substances like penicillic acid are present, the characteristic color develops in the aqueous layer.

¹ Pelloggio, Pietro. *Materia reagente quale alcaloide, trovata nell' estratto del mais guasto preparato dall' Erba.* Reale Istituto Lombardo, Rendiconti, s. 2, v. 9, p. 118-121, 1876.

² Lombroso, Cesare, and Erba, Carlo. *Loc. cit.*

Biffi, S. Sulla nota del prof. Cesare Lombroso: I veleni del mais e la pellagra. Reale Istituto Lombardo di Scienze e Lettere, Rendiconti, s. 2, v. 9, p. 282-288, 1876.

³ Lombroso Cesare. I veleni del mais e la loro applicazione all'igiene ed alla terapia. *Rivista Clinica di Bologna*, s. 2, ann. 7, p. 109-112, 1877.

— and Erba, Carlo. *Op. cit.*

⁴ Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 199, 1910.

⁵ Gosio, B. Ricerche batteriologiche e chimiche sulle alterazioni del mais. *Rivista d' Igiene e Sanità Pubblica*, ann. 7, p. 825-849, 899-898, 1896.

⁶ Gosio, B. Alterazioni del granturco e loro profilassi. Italy, Direzione generale dell' Agricoltura, *Annali di Agricoltura*, no. 261, 1909.

When the tests are conducted in this way the number of samples of obviously deteriorated maize showing the reaction is greater than when the unmodified Gosio test is employed. Nevertheless, a positive result seems to be less frequent in American maize than in Italian maize. Moreover, the colors obtained with American spoiled maize have always been found to be red or red brown, while in Italy tests of spoiled corn are most commonly described as showing violet, blue, purple, and greenish tints. None of these tints have been encountered in American maize in this laboratory.

Since this sharp difference apparently exists between American and Italian deteriorated maize, it is desirable to compare samples of Italian spoiled maize with American ones. Opportunity to make this comparison was offered by Dr. C. H. Lavinder, of the Public Health Service, who while on a visit to Italy very kindly secured samples of condemned maize.

From one of these samples of maize Dr. E. F. Smith, of this Bureau, isolated two species of *Penicillium*. One of these species was identified by Dr. Charles Thom, of the Storrs Agricultural Experiment Station, as *P. stoloniferum* Thom.¹

This organism when grown on Raulin's medium gives the very strong and characteristically violet ferric-chlorid reaction of Gosio. It is certainly a remarkable fact that the first sample of spoiled Italian corn examined gave the violet color described by Italian authors, whereas no American sample has been found giving a similar tint.

It was therefore decided to isolate, if possible, the substance responsible for the ferric-chlorid reaction. For this purpose the organism from Italian spoiled corn was grown in "Long Blake" bottles on Czapek's medium and on Raulin's medium in the manner above described. It was found that the organism grew more rapidly upon Raulin's medium. Therefore, for the preparation of material Raulin's medium only was used.

The substance responsible for the ferric-chlorid reaction was isolated by the following procedure: The culture fluid and the mycelium were transferred to an evaporating dish and rendered weakly alkaline with sodium carbonate. The contents of the dish were then heated to boiling and filtered hot. The mycelium remaining on the filter was thoroughly expressed. The mass was then again extracted with water rendered weakly alkaline with sodium carbonate. The combined extracts were evaporated to a small bulk over a free flame and filtered hot. To the clear filtrate a slight excess of hydrochloric acid was added. An abundant precipitate

¹ Thom, Charles. Cultural studies of species of *Penicillium*. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 118, 1910.

was produced, which consisted of a mixture of needle clusters and amorphous material. The precipitate was separated by filtration and washed with cold water. After drying spontaneously it was extracted with hot toluene and the hot extract filtered. Only the crystalline portion of the precipitate dissolved. The amorphous dark-brown material which remained on the filter was discarded, for it did not give a color reaction with ferric chlorid. On cooling and evaporating, the toluene extract spontaneously precipitated in the form of needles, the material giving the ferric-chlorid reaction. These needles, which were still slightly colored, were finally obtained white either by decolorizing with boneblack in hot toluene solution or by dissolving in alcohol and adding alcoholic potassium hydroxid to form the potassium salt, which is insoluble in alcohol. This salt was then washed free from color with alcohol. From the potassium salt the free acid was recovered in the form of white needles by dissolving the salt in water and precipitating with hydrochloric acid.

The substance thus obtained consists of white needles with a melting point of 140°C ., uncorrected. The name mycophenolic acid is provisionally suggested for it. It is almost insoluble in water, but freely soluble in alcohol, in ether, and in chloroform. It is somewhat less soluble in benzene, only moderately soluble in cold toluene, and very soluble in hot toluene. With ferric chlorid it gives a violet color in aqueous solution, though its solubility in water is not sufficient to render the color intense. In alcoholic solution it gives a bright-green color with ferric chlorid. It does not react with Millon's reagent. It does not give Lieberman's reaction and could not be diazotized. It does not reduce Fehling's solution nor ammoniacal silver nitrate. It is fairly resistant to sodium, ammonium, and potassium hydrates and to hydrochloric, sulphuric, and acetic acids, being unaffected by boiling in 10 per cent solutions of any of these reagents. It does not contain water of crystallization. Its salts of potassium and sodium are very soluble in water. The salt of potassium is soluble in dilute alcohol, but insoluble in absolute alcohol. The salt of sodium is soluble in absolute alcohol, but may be precipitated in crystalline form by adding ether. The salt of barium is only very slightly soluble in water and forms clusters of minute needles. The copper, lead, and silver salts are amorphous and insoluble in water. In characterization of the substance the facts collected in Table V were ascertained by analysis of the free acid, by titration of the alcoholic solution of the free acid with $n/10$ sodium hydroxid, and by the determination of the barium content of the salt on ignition in platinum with sulphuric acid.

TABLE V.—*Analyses of mycophenolic acid.*

Weight of substance.	CO ₂ .	H ₂ O.	C.	H.	BaSO ₄ .	Ba.	N/10NaOH.
<i>Gram.</i>	<i>Gram.</i>	<i>Gram.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Gram.</i>	<i>Per cent.</i>	<i>C. c.</i>
0.2816.....	0.5419	0.1315	63.81	6.30			
.2044.....	.4770	.1161	63.64	6.31			
.2404.....					0.1206	29.65	
.1900.....							11.53
Average..			63.726	6.305			

Calculated for C₁₇H₂₀O₆: carbon, 63.74 per cent; hydrogen, 6.25 per cent.

Found..... carbon, 63.72 per cent; hydrogen, 6.30 per cent.

Calculated for Ba (C₁₇H₁₅O₆): barium, 29.15 per cent.

Found..... barium, 30.09 per cent.

A molecular weight determination by the elevation of the boiling point in chloroform solution gave the results shown in Table VI.

TABLE VI.—*Ebullioscopic determination of the molecular weight of mycophenolic acid.*

Weight of substance.	Weight of solvent.	Rise of boiling point.	Molecular weight.
<i>Gram.</i>	<i>Grams.</i>	<i>Degree C.</i>	
0.1041.....	30.32	0.065	308
.1578.....	30.32	.060	321
Average..			314.5

Molecular weight calculated for C₁₇H₂₀O₆..... 320

Molecular weight found from titration..... 345. 4

Molecular weight found from barium content of salt..... 328

Molecular weight found from boiling-point elevation..... 314. 5

The formula C₁₇H₂₀O₆ may therefore be assigned to mycophenolic acid. It does not readily decompose carbonates at ordinary temperatures. It is apparently a dibasic acid, or, at any rate, combines with two atoms of a monovalent base. Whether the base combines entirely with carboxyl groups or with phenol groups has not been determined.

The acid seems to form two series of salts. Presumptive evidence on this point was obtained by the following experiments: Two decigrams of free acid were suspended in water and one equivalent of potassium hydroxid added. Unfortunately, this quantity was not sufficient to dissolve the substances completely, so that a slightly greater quantity of the alkali had to be used. This solution was then treated with one equivalent of barium chlorid. On standing in the desiccator a crystalline barium salt formed. This salt was evidently different from the normal barium salt, which is so insoluble that it precipitates at once. It was also of different appearance under the microscope, consisting of a few small needles in clusters, which appar-

ently were the normal salt, and more abundant larger single needles, apparently the acid salt. The presence of the normal salt in small quantities under the conditions of the experiment was probably due to the fact that an excess of alkali had to be used in dissolving the substances. The barium content of this preparation was determined, 0.207 gram yielding 0.0692 gram of BaSO_4 , equivalent to a barium content of 20.2 per cent.

Calculated for $\text{Ba} (\text{C}_{17}\text{H}_{10}\text{O}_6)$	28.1 per cent.
Calculated for $\text{Ba} (\text{C}_{17}\text{H}_{10}\text{O}_6)_2$	17.7 per cent.
Found	20.2 per cent.

Apparently, as shown by the microscope, the preparation consisted of a mixture of two salts.

It has not been found possible to identify mycophenolic acid with any known compound. The substance of Gosio referred to above very greatly resembles it, though these substances are probably not identical. However, Gosio's characterization of this substance was based on a very small quantity of material, so that his formula $\text{C}_9\text{H}_{10}\text{O}_6$, based on a single combustion, can not be regarded as final. The chief points of difference between the substance described by Gosio and mycophenolic acid are the percentage composition and the behavior with ferric chlorid. Gosio's substance gives an intense blue color with ferric chlorid in alcoholic solution. Mycophenolic acid gives a violet color in aqueous solution, while in alcoholic solution with a trace of ferric chlorid it gives a violet color which becomes bright green on addition of an excess of the reagent.

In one particular mycophenolic acid resembles Gosio's substance but differs from penicillic acid. It is not toxic. Ten milligrams were dissolved in water with the aid of a little sodium carbonate and injected subcutaneously into a mouse. No untoward effects whatever were noted. It differs furthermore from penicillic acid in being present chiefly in the mycelium in the early stages of growth. In old cultures it is found both in the culture fluid and in the mycelium, perhaps because with the gradual production of basic substances it is dissolved. The question whether toxic phenolic substances are found in the culture fluid or only in the mycelium is one that has been much discussed by students of pellagra. When the substances are insoluble acids with soluble salts like mycophenolic acid, their distribution is probably only a question of the reaction of the medium. When the reaction is acid they will be found in the mycelium, as lichen acids incrust the lichen thallus. When the medium contains available bases they will become more or less dissolved in the medium.

With the advancing age of the culture, mycophenolic acid gradually increases in quantity until under the conditions employed in these experiments at the end of two weeks the maximum yield is obtained.

After that time the quantity present is apparently constant. When grown in the "Long Blake" bottles charged with 250 cubic centimeters of culture fluid, the yield at the end of about two weeks averages about 0.07 gram of the crude acid per bottle.

Since *Penicillium stoloniferum* is found so commonly in the United States and has been isolated in this laboratory from spoiled maize, it is not easy to understand why it so rarely, if ever, causes spoiled maize in the United States to give the ferric-chlorid reaction. The first explanation to present itself was that the American organism might be a different strain or perhaps a "physiological variety."

To solve this question, Dr. Thom very kindly furnished a specimen of his type culture. This specimen was grown side by side with the Italian organism. It grew rather more slowly than the latter and there were slight differences in appearance. The cultures gave a good ferric-chlorid reaction, very similar in shade to that given by the Italian organism, but when the attempt was made to separate mycophenolic acid from the cultures of the American organism none could be found. In its place was found a quite different substance or mixture of substances. As this material has not yet been obtained in satisfactory crystalline form, not much can at present be said of its properties.

The different biochemical behavior of the two strains from the two continents is certainly suggestive. Whether these two strains are really physiologically different can not as yet be decided. The American organism used is an old one, having been propagated by Dr. Thom in the laboratory for a number of years. Possibly this long artificial propagation has altered its behavior. It is proposed to continue the investigation of this problem by comparing the two cultures on hand with a number of other recently isolated strains.

No extended physiological studies were undertaken on *Penicillium stoloniferum*. A few observations were made incidentally. The organism always produced alcohol, as shown by applying the iodoform test to the distillate. No quantitative determinations were made, but the amount of alcohol formed, as judged by the iodoform test, seemed to be decidedly less than that produced by *P. puberulum*. *P. stoloniferum* produces a small amount of oxalic acid, as shown by the method used for *P. puberulum*. It seems to be present in somewhat larger amounts and at an earlier stage of growth than in cultures of *P. puberulum*. Finally the mycelium of *P. stoloniferum* seems to be very rich in mannitol.

SUMMARY.

Of six species of *Penicillium* from maize examined, only two elaborated substances toxic to mice. Two of these species, one toxic, the other nontoxic, were studied in detail.

The first, identified as *Penicillium puberulum* Bainier, elaborates a toxic product which was isolated and for which the name "penicillic acid" and the formula $C_8H_{10}O_4$ are suggested. This substance behaves like a monobasic acid. It is toxic to animals when injected subcutaneously, causing death in a dosage of about 0.2 to 0.3 gram per kilo of body weight. The formation of penicillic acid is more abundant when the air supply is limited and the reaction of the medium is acid. The form in which nitrogen was offered the fungus seems also to have some influence on its formation.

Penicillium puberulum Bainier was always found to produce alcohol when grown in the presence of sugar. Old cultures contain minute amounts of oxalic acid. In the presence of sugar and leucin no amyl alcohol is produced, although leucin is consumed. A small quantity of volatile acid is, however, formed. In the presence of sugar and tyrosin neither tyrol nor tyrosol is produced, though tyrosin is consumed. A small quantity of volatile acid is formed.

The second organism, *Penicillium stoloniferum* Thom, was nontoxic. Unlike the other five studied, it was isolated from Italian maize. It elaborates a new phenolic acid, for which the name mycophenolic acid and the formula $C_{17}H_{20}O_6$ are suggested. This substance behaves like a weak dibasic acid and, like penicillic acid, resembles the lichen acids in many ways. Among the other metabolic products of the organism, alcohol, oxalic acid, and mannitol were found.

In the present paper it has been shown that species of *Penicillium* so closely related that until recently they were not distinguished by morphologists differ quite markedly in their metabolism. It is greatly to be desired that the whole genus be studied biochemically. The chemical findings will no doubt supplement the morphological in many important ways. Indeed, as indicated by the constant presence of alcohol and the formation of penicillic acid by *Penicillium puberulum* and the formation of mycophenolic acid by *P. stoloniferum*, it is not impossible that characteristic chemical properties may help to distinguish between species or strains not now sharply separated by morphologists.

Therefore the present investigation furnishes additional data for explaining the discrepancies in different biochemical investigations on molds. Previous investigators may have failed to realize that the products elaborated vary with the species, with the reaction of the medium, with the aeration, and perhaps with the nature of the nitrogenous food supply, and that it is exceedingly difficult to distinguish between quite distinct species. They may also have underestimated the difficulties of distinguishing between the individual species.

Issued December 31, 1912.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 271.

B. T. GALLOWAY, *Chief of Bureau.*

SOME EFFECTS OF REFRIGERATION ON SULPHURED AND UNSUL- PHURED HOPS.

BY

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AND

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Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, BEVERLY T. GALLOWAY.
Assistant Chief of Bureau, WILLIAM A. TAYLOR.
Editor, J. E. ROCKWELL.
Chief Clerk, JAMES E. JONES.

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., September 18, 1918.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 271 of the series of this Bureau a manuscript by Dr. W. W. Stockberger, Physiologist, and Mr. Frank Rabak, Chemical Biologist, entitled "Some Effects of Refrigeration on Sulphured and Unsulphured Hops," submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

In this paper is discussed some of the changes which occur in important constituents of hops under different conditions of storage and a comparison is made of the relative efficacy of certain methods for preventing undesirable changes in hop constituents.

This bulletin shows that both refrigeration and sulphuring retard changes in the volatile constituents of hops and that the determination of the value of hops from the aroma varies according to individual preference for or dislike of one or the other of the aromatic constituents. The conclusions drawn from a comparison of valuations made from both physical and chemical standpoints will be of practical importance to all interested in the hop industry.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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SOME EFFECTS OF REFRIGERATION ON SULPHURED AND UNSULPHURED HOPS.

INTRODUCTION.

Opinions are greatly divided as to the desirability or general expediency of the practice of treating hops with the fumes of burning sulphur during the process of drying. This process, which in the United States is termed "sulphuring," has been long in vogue and has come to be regarded as an essential part of the method of preparing hops for market. The use of sulphur as an adjunct to hop drying apparently originated in England and from the first was regarded as a more or less effective means of checking the tendency of newly packed hops to heat and spoil in the bale. Later, other virtues were claimed for sulphuring in addition to that of preservative action, and those who advocate the use of sulphur now believe that it favorably affects the hops by changing and improving the color, by hastening the drying through causing the rapid death of the cells, and by preventing fermentation, thereby improving the keeping qualities.

Aside from sulphuring, a number of other expedients have been resorted to for the purpose of delaying or retarding the changes which normally occur in the chemical constituents of hops after they have been dried and baled. Of these expedients refrigeration is the most widely used and from many considerations it is perhaps the most efficient and generally satisfactory method of preservation that has as yet been employed.

The sulphuring of hops is such a common practice in the United States that practically all hops placed in cold storage may be regarded as having absorbed a varying quantity of sulphurous acid, depending to a certain extent upon the quantity of sulphur used at the time of drying. Since both sulphuring and cold storage are held to be efficient agents in retarding changes in the essential constituents of hops, the diminished rate of deterioration of sulphured hops in cold storage must be due to the combined action of these two processes. However, the relative efficacy of these two processes,

or the extent to which the one or the other alone would accomplish the desired result, is usually a subject of approximate estimation only.

For the purpose of obtaining some experimental data upon the preservative action on hops of sulphuring and cold storage, singly and in combination, suitable material was prepared and held under observation for several years. The results of this study, which are given in some detail in this bulletin, indicate that both cold storage and sulphuring tend to delay certain undesirable chemical changes and that the usual trade judgment can not always be relied upon to give an accurate measure of the extent to which these changes have occurred. However, it is fully realized by the writers that further experimentation is necessary before the conclusions drawn from this work can be considered to have a general application.

PREPARATION OF THE HOPS STUDIED.

The hops which furnished the materials for the observations here recorded were all picked from the same part of a field on a hop ranch in the Sacramento Valley on August 30, 1907, and were dried on the same day under the senior writer's supervision. As the hops were received from the field they were equally distributed to two duplicate stove kilns until each had received a load of about 4,500 pounds, green weight. The fires were lighted and the temperature of each kiln was gradually raised to a point between 130° and 140° F., between which limits it was maintained until the drying was completed. On one of these kilns 110 pounds of sulphur was burned under the hops during the drying, which required 13 hours; on the other kiln no sulphur was used and the time required for drying was 18 hours. The dry hops from each of these two kilns were separately deposited in the cooling room and on September 2 two bales of the usual commercial type were prepared from the unsulphured hops and two from those which had been heavily sulphured. These four bales were conveyed to Sacramento, where two bales, one of sulphured and one of unsulphured hops, were placed in cold storage at 36° F. in the hop storeroom of the Buffalo Brewing Co., and the two remaining bales, one of which was sulphured and one unsulphured, were placed in ordinary storage in the Clunie warehouse.

PHYSICAL CHANGES IN THE HOPS IN COLD AND IN ORDINARY STORAGE.

As a rule, it is difficult to correlate the valuation of hops as determined from their physical characters with the indications of their value derived from chemical analysis. In the present case, however,

some chemical determinations were made which are not ordinarily taken into account in analyzing hops, and the results furnish some interesting parallels when compared with the relative rank in quality of the four bales of hops as fixed by physical valuation.

In order to have the differences in physical condition expressed in the language of the trade and as nearly as possible from the trade viewpoint, samples were drawn from time to time from the four bales and submitted to various trade experts, who were asked to report their impressions as to the general condition and relative merit of the various samples.

Early in April, 1908, after the hops had been in storage for seven months, samples were drawn from each of the four bales and submitted to five trade experts, all of whom concurred in the following report made by one of their number:

We have examined these samples as to their condition at the present time to see if there was any difference between cold and regularly stored hops, and we are of the same opinion that there is no difference between the cold-stored and regularly stored hops.

The bales were not sampled a second time until midsummer, and during the time which had elapsed since the first sampling the hops in ordinary storage had been subject to the influence of the hot and dry weather which prevails in the Sacramento Valley at this season of the year. Naturally, it was expected that at this time certain differences would be apparent in the hops under different conditions of storage. On July 24, 1908, samples were drawn and submitted to an expert hop buyer, who reported on them as follows:

Unsulphured cold-stored hops.—Fine fresh hop flavor; good oily feeling; aroma almost as good as new hops and seems to be about the same as that of the sulphured cold-stored hops.

Sulphured cold-stored hops.—Fine fresh hop flavor; good oily feeling; aroma almost as good as new hops, but color somewhat lighter than the color of the unsulphured sample above described.

Unsulphured ordinary-stored hops.—Flavor decidedly that of old hops as compared with the cold-stored samples; feeling dry; lupulin not very sticky; color about the same as the color of the unsulphured sample above.

Sulphured ordinary-stored hops.—Fine fresh flavor; good oily feeling; aroma almost as good as new hops, but the color somewhat lighter than the color of the unsulphured sample above described.

At this time it is decidedly noticeable that the cold-stored hops have by far the best flavor and that they feel almost as oily as new hops, while the ordinary-stored hops are becoming poorer.

This judgment was taken within an hour after the bales had been sampled, and on coming into the room where the samples had been placed I thought that the excellent aroma was due to new hops. I was really surprised at the great difference in the aroma between the ordinary-stored and cold-stored hops, but

on comparing color I can not notice any serious difference between sulphured and unsulphured hops in either case.

These same samples were next submitted to a second expert, who made the following statement:

The difference between the ordinary-stored and the cold-stored hops is now very noticeable. The unsulphured cold-stored sample has a very good flavor and looks fresh and bright. The unsulphured ordinary-stored sample has not such a good flavor as the former, is very much drier, and is becoming rapidly aged. The difference between these two is particularly noticeable in the appearance of the sides of the samples, the side of the cold-stored sample showing up much brighter and fresher than that of the other.

The sulphured cold-stored sample has a fine fresh flavor and is a particularly well-kept hop, while the sulphured ordinary-stored sample has a musty, old flavor and is rather dried out. The difference between these two samples is not so much in the appearance as in the aroma.

On the day following, these samples were submitted to a brewmaster, who delivered the following opinion:

The cold-stored hops have a lighter color as compared with the ordinary-stored hops, the lupulin is bright and shiny, the hops have a very oily and sticky feeling, and the aroma is almost like that of new hops.

The ordinary-stored hops have a dull, dry color; the lupulin is not so bright and appears to be hard and dry, with very little oil as compared with the cold-stored hops; the flavor is decidedly different and very much like that of old hops.

The bales were not sampled again until February 13, 1909, eighteen months after they were first placed in storage. The samples drawn on this date were first submitted to the brewmaster previously mentioned, and his judgment as to their relative merit was stated thus:

The sulphured and unsulphured cold-stored samples are respectively superior in flavor to the corresponding ordinary-stored samples. The sulphured samples in cold and ordinary storage are far superior both in flavor and color to the unsulphured samples.

The samples were next submitted to a trade expert, who gave the following opinion:

There is a very great difference between the cold-stored and ordinary-stored hops. The cold-stored samples are much brighter in appearance, have much more flavor, contain much more moisture, and their lupulin is much brighter than the ordinary-stored samples. The cold-stored samples would pass for new hops, while the ordinary-stored samples show their age and could not pass for anything else than "olds." By new hops I mean the 1908 crop.

Of the cold-stored hops the unsulphured sample seems to have a trifle more flavor than the sulphured one, but the latter has a sweeter flavor, which I believe would be preferred. The lupulin in both these samples is very fresh and moist, but that in the sulphured sample is a trifle the brighter. The sulphured sample, though in appearance fresher than the unsulphured sample, is not as moist as the latter.

Of the ordinary-stored hops the unsulphured sample has much more flavor than the sulphured sample, the latter having very little flavor at all. The

lupulin in the sulphured sample is a trifle brighter than that in the other. The unsulphured sample is much more moist than the sulphured sample, though the latter, before a detailed examination, appears to be the fresher of the two, a condition that can be traced to the brightening effect of the sulphur.

Since the sulphured cold-stored hops naturally conformed most closely in appearance and general condition to the hops usually found in the trade it was expected that they would be ranked first in quality, and such proved to be the case when the several expressions of judgment by the trade experts were analyzed. With respect to the other lots of hops, however, opinion was divided and the usual differences in trade judgment of quality are here well illustrated. The rank in order of merit as fixed by four of the judges was as follows:

Sulphured cold-stored hops.....	1.	1.	1.	1.
Unsulphured cold-stored hops.....	2.	2.	3.	2.
Sulphured ordinary-stored hops.....	3.	4.	2.	4.
Unsulphured ordinary-stored hops.....	4.	3.	4.	3.

CHANGES IN THE VOLATILE CONSTITUENTS OF HOPS IN COLD AND IN ORDINARY STORAGE.

On September 10, 1909, portions of the four bales of hops under consideration were withdrawn from storage and subjected to steam distillation to remove the volatile oils, which were then dried and purified and later examined to determine their degree of acidity and ester content. These factors, together with the percentage of yield of volatile oil, are given in Table I.

TABLE I.—Comparison of volatile oils from sulphured and unsulphured hops in cold and in ordinary storage for two years.

Source of oil examined.	Percent- age of oil.	Acid number.	Ester number.
Sulphured cold-stored hops.....	0.12	7.3	78
Unsulphured cold-stored hops.....	.12	9.0	103
Sulphured ordinary-stored hops.....	.06	12.5	96
Unsulphured ordinary-stored hops.....	.06	15.6	151

An inspection of this table reveals the following interesting facts:

(1) The yield of oil is twice as great in the cold-stored hops as in those in ordinary storage.

(2) The acidity of the oil from the cold-stored hops is far less than that of the hops in ordinary storage.

(3) The oil from the sulphured hops in ordinary storage shows an increase of 71.2 per cent in acidity over that from the hops in cold storage, while the oil from the unsulphured hops in ordinary storage shows an increase of 73.3 per cent in acidity over that of the oil from those in cold storage.

(4) The oil from the unsulphured cold-stored hops shows an increase of 23.2 per cent in acidity over that from the hops that were sulphured, while the oil from the unsulphured, ordinary-stored hops shows an increase of 24.8 per cent in acidity over that from the hops that were sulphured.

(5) The oil from the unsulphured ordinary-stored hops shows an increase of 113.6 per cent in acidity over the oil from sulphured cold-stored hops.

(6) The ester content of the oil from the sulphured hops is much less than that of the oil from the unsulphured hops.

(7) The oil from the unsulphured ordinary-stored hops shows an increase of 23 per cent in ester content over that from the hops in cold storage, while the oil from the unsulphured hops in ordinary storage shows an increase of 46.6 per cent in ester content over the oil from those in cold storage.

(8) The oil from the unsulphured cold-stored hops shows an increase of 32 per cent in ester content over the oil from the sulphured cold-stored hops, while the oil from the unsulphured ordinary-stored hops shows an increase of 57.2 per cent in ester content over that from the sulphured hops in ordinary storage.

(9) The oil from the unsulphured ordinary-stored hops shows an increase of 93.5 per cent in ester content over that of the oil from the sulphured cold-stored hops.

This analysis gives an index of the relative efficacy of sulphuring and cold storage in controlling changes in acidity and ester content of the hop oils during the first two years of storage. The percentages of increase in acidity as between cold and ordinary storage are approximately three times the corresponding increase as between the sulphuring and nonsulphuring. This would apparently indicate that cold storage is three times as effective as sulphuring in retarding increase in acidity. With respect to ester content, the increase, as between the oils from cold and ordinary stored hops, is twice as great in unsulphured as in sulphured hops; also as between sulphured and unsulphured hops the increase in the ester content of the oil is twice as great in ordinary storage as in cold storage. This would seem to show that cold storage and sulphuring are about equally effective in retarding the increase in the ester content and that the two combined exert double the effect of either acting alone.

On December 1, 1910, fifteen months later, a second set of samples was taken from the four bales in storage and the volatile oils removed by distillation. The results of the examination of these oils, which are given in Table II, show little harmony with those of the first analysis.

TABLE II.—*Comparison of volatile oils from sulphured and unsulphured hops in cold and in ordinary storage for three years and three months.*

Source of oil examined.	Acid number.	Ester number.
Sulphured cold-stored hops.....	30.8	129.5
Unsulphured cold-stored hops.....	33.1	126.1
Sulphured ordinary-stored hops.....	24.0	106.0
Unsulphured ordinary-stored hops.....	24.0	109.0

An inspection of the table shows in this case the following relations:

(1) The acidity of the oil from the cold-stored hops is greater than that of the oil from the hops in ordinary storage.

(2) The acidities of the oils from the hops in ordinary storage are the same.

(3) The oils from the unsulphured cold-stored hops are highest in acidity.

(4) The ester content of the oils from the cold-stored hops is greater than that of the oils from the ordinary-stored hops.

(5) The oils from the sulphured hops in cold storage are highest in ester content.

(6) The oils from the unsulphured hops in cold and in ordinary storage, respectively, are higher in ester content than the oil from the sulphured hops in ordinary storage.

It is now evident that the apparent effects of sulphuring and cold storage as shown by the second analysis are almost the reverse of those indicated by the first analysis. How these seeming discrepancies may be harmonized can be seen from an inspection of Table III, in which the results of the two analyses are directly compared.

TABLE III.—*Comparison of the acidity and ester content of the oils from sulphured and unsulphured hops in cold and in ordinary storage.*

Kind of stor- age.	Sulphured hops.						Unsulphured hops.					
	Acid num- ber.		Per- cent- age of in- crease, 1910.	Ester num- ber.		Per- cent- age of in- crease, 1910.	Acid num- ber.		Per- cent- age of in- crease, 1910.	Ester num- ber.		Per- cent- age of in- crease, 1910.
	1909	1910		1909	1910		1909	1910		1909	1910	
Cold.....	7.3	30.8	321.9	78	129.5	66.0	9.0	33.1	267.4	108	126.1	22.4
Ordinary.....	12.5	24.0	92.0	96	105.0	9.3	15.6	24.0	53.8	151	109.0	7.7

Regarding, first, the acidity, the data in this table show that the percentage of increase in acidity was least in the oils from the hops which yielded oils that were highest in acidity in 1909 and greatest

in those lowest in acidity in 1909. Further, all the percentages of increase in acidity in 1910 are inversely proportional to the acidities in 1909. It is evident from the first analysis that the rate of change in the volatile constituents under consideration was greatest in the oils from the unsulphured hops in ordinary storage. These changes would continue until a maximum was reached, after which, owing to the interaction between the oxidation products of the various organic constituents of the hops and to the direct loss through volatilization, a decline in acidity would be the normal result. Assuming that this maximum was reached between the time of the first and the second analysis and applying this explanation to the data on acidity in Table III, the oils from the hops in ordinary storage may be regarded as having passed the maximum and as being in the declining phase with respect to acidity. Since the changes in the unsulphured hops in ordinary storage were not artificially retarded, the oils from these would naturally be nearer than the others to the maximum acidity at the time of the first analysis, and hence the percentage in increase in 1910 would be smallest.

Of the hops in cold storage, the oils from those that were unsulphured may be regarded as being at or near the maximum of acidity in 1910, thus accounting for the high figure of actual acidity and for the relatively large percentage of increase in acidity during this year. On the other hand, the oils from the sulphured cold-stored hops had apparently not reached the maximum acidity in 1910, owing to the slower rate of change in acidity in these oils due to the combined effect of sulphuring and cold storage. When viewed from this standpoint, the apparent discrepancy between the two analyses disappears and the balance of evidence is in favor of the conclusion (1) that under the four conditions of this experiment the acidity of the oil of hops increases to a maximum and then declines; (2) that sulphuring and cold storage merely retard but do not inhibit changes in acidity; and (3) that sulphuring and cold storage combined are more effective in retarding changes in acidity than either alone.

With respect to the esters, the data indicate that, in general, the changes in ester content have been similar to the changes in the acidity, although complicated by some other factors which make the relations of these changes to the conditions of storage less clear. The first analysis shows that the greatest changes in ester content occurred in the oils from the unsulphured hops and also that the oils from the hops in ordinary storage had undergone a greater change than the corresponding oils from the sulphured and unsulphured hops, respectively, in cold storage. It is possible that the

sulphur inhibits the development of ester beyond a certain point, in which case two maxima might be expected—one for the oil from sulphured hops and a higher one for the oil from unsulphured hops. The data of Table III agree with this assumption, for it appears that the oils of the unsulphured ordinary-stored hops were at or near the maximum of ester content in 1909, which thereafter rapidly declined, as shown by the figure reached in 1910.

The oil from the unsulphured cold-stored hops, which was below the probable maximum of ester content at the time of analysis in 1909, shows an apparent increase of 22.4 per cent in 1910; but, since the figure reached in 1910 is less than the probable maximum as indicated by the ester content of the oils from the hops in ordinary storage in 1909, it seems evident that the oils in the hops in cold storage had reached the maximum and entered upon the declining phase before the analysis in 1910. This view receives further support from the fact that the oil from the sulphured cold-stored hops, in which the chemical changes were most retarded, was higher in ester content in 1910 than the oil from those which were unsulphured.

The oils of the sulphured hops in ordinary storage appear to have passed their maximum of ester content and to be in the declining phase in 1910, while those of the hops that were sulphured and which show the greatest increase in ester content in 1910 appear to be at or near their maximum. The conclusions which are to be drawn with respect to the ester content, therefore, are that sulphuring retards the increase in ester content and inhibits it beyond a certain maximum, that cold storage retards but does not inhibit increase in ester content, and that sulphuring and cold storage combined are more effective in retarding changes in ester content than either alone.

CHANGES IN THE HOP RESINS.

In further pursuance of the plan of securing trade opinions with respect to the changes which had taken place in the four bales of hops under different conditions of treatment, portions of these bales were sent to a firm which is a large consumer of hops, with the request that the content of soft and hard resins be determined in each. The first analysis was made by the chemist of this firm in January, 1910, two years and four months after the bales had been first placed in storage. One year later a second lot of samples was sent to the same chemist and by him duly analyzed. The results of these two analyses are given in Table IV.

TABLE IV.—*Changes in resin content in sulphured and unsulphured hops in cold and in ordinary storage.*

Previous treatment of the hops analyzed.	Percentage of resins.					
	Soft resins.		Hard resins.		Total resins.	
	1910	1911	1910	1911	1910	1911
Sulphured, cold stored.....	10.5	10.2	5.5	5.6	16.0	15.9
Unsulphured, cold stored.....	10.6	8.7	5.3	6.2	15.9	14.9
Sulphured, ordinary stored.....	9.9	7.5	5.5	7.5	15.4	15.0
Unsulphured, ordinary stored.....	9.9	7.8	7.0	6.4	16.9	14.2

The figures in the foregoing table give an index to the changes which occurred in the resin content of these hops during the third year of storage. The slightest change in total resins, 0.1 per cent, took place in the sulphured cold-stored hops, while the greatest change, 2.7 per cent, is evident in the unsulphured hops in ordinary storage. The loss in soft resins was least in the sulphured cold-stored hops, 0.2 per cent, and greatest in the sulphured ordinary-stored hops, 2.4 per cent. The loss in soft resins of the unsulphured hops was 1.9 per cent in cold storage and 2.1 per cent in ordinary storage. As far as the evidence from these analyses goes, it indicates that sulphuring diminishes the loss of total resins, but does not diminish the loss of soft resins except when followed by cold storage. The greatest loss in soft resins was in the sulphured hops in ordinary storage, and, since the soft resins alone are intrinsically valuable, from this standpoint these hops must be regarded as the poorest of the lot. With respect to these particular samples, the balance of evidence indicates that there is a distinct advantage in both sulphuring and cold storage. However, the margin of difference in the results of the analyses is relatively small, and if the soft resins were regarded as the only measure of value, the advisability of incurring the expense of long-continued cold storage might be questioned.

PHYSICAL AND CHEMICAL VALUATION COMPARED.

Great difficulty is experienced not only in harmonizing the results of the physical and chemical estimations of the value of hops, as pointed out on a previous page, but also in bringing into accord the different individual judgments of quality, determined on a purely physical basis. This point has been discussed at some length in a previous publication¹ and will not be dwelt upon here further

¹ Stockberger, W. W. The Necessity for New Standards of Hop Valuation. Circular 33, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

than to state that it is well-nigh impossible to find two persons who will assign the same rank in value to six samples of commercial hops selected at random. Some light is thrown on these differences in judgment by a study of the different opinions rendered as to the relative value of the four lots of hops, all from the same source but subject to different conditions of treatment and storage. In order to bring out clearly some of the contrasts in these opinions, a table was prepared in which the physical and chemical valuations are compared. In this table the relative rank given each lot of hops by the four expert judges is indicated by the corresponding numeral.

The relative rank in acidity of the oils, which is similarly indicated, was determined from the results of the first analysis, since this analysis was made nearest in point of time to the physical valuations. The hops having the oils lowest in acidity were given the highest rank, those with oils next in acidity second rank, and so on, this order being determined by the fact that the hops having oils lowest in acidity had changed least from the original condition at the time of first storage. The relative rank with respect to ester content was determined in the same manner. The relative rank with respect to resins was determined from the content of soft resins, as these alone are considered to be the only resins of value in the utilization of hops. Since keeping quality, as indicated by a slow rate of change in the chemical constituents, is an important factor of value it was made the basis of relative rank in this case rather than the absolute quantity of soft resin. This relative keeping quality was determined from the difference in the content of soft resins, as shown by the two analyses. A direct comparison of all these relative rankings may be made from Table V.

TABLE V.—*Comparisons of rankings in value of sulphured and unsulphured hops in cold storage and in ordinary storage.*

Previous treatment of the hops.	Rank in value determined as noted.						
	By trade experts.				By acidity.	By ester content.	By keeping quality of soft resins.
	A.	B.	C.	D.			
Sulphured, cold stored.....	1	1	1	1	1	1	1
Unsulphured, cold stored.....	2	2	3	2	2	3	2
Sulphured, ordinary stored.....	3	4	2	4	3	2	4
Unsulphured, ordinary stored.....	4	3	4	3	4	4	3

From this table it appears that the rankings as to value are consistent in one case only, that of the sulphured cold-stored hops. However, on taking the judgments of the trade experts singly, that of expert A will be seen to agree with the rankings determined by

acidity, that of expert C with the rankings with respect to ester content, while the rankings of experts B and D agree with the order determined by the keeping quality of the soft resins. The reason for the differences in the judgments, based largely, if not entirely, upon the flavor or aroma of the hops, seems to lie, in part at least, in the difference of degree of sensitiveness of the individual to the several volatile constituents, which together form the aroma. It is well known that odors which are agreeable to some persons affect others unfavorably, and there is every reason to believe that in the present case the differences in judgment were due to the physiological idiosyncrasies of the observers. That this point of view is coming into wider recognition is shown by the following statement made by Dr. Albert Fischer:

The determination of aroma is an entirely individual matter, depending upon the individual taste, the state of health, and the eventual influence of outside flavors on the person testing.¹

However, since the number of individuals who passed judgment upon the experimental samples was small, the decisions rendered are not necessarily conclusive and certainly do not prove that the aroma should not be used as a factor in the determination of the value of hops. That the aroma is useful in determining the age and soundness of hops is conceded even by those who hold that it is not a proper factor from which to determine intrinsic value. The term "age" may be used to express the time that has elapsed since the hops were harvested or, in a relative sense, to denote the extent to which unfavorable changes have occurred in the hops. The hops under discussion here were of the same actual age, but owing to the different conditions of treatment they were of different relative ages, as shown by the different points to which the changes in the chemical constituents had progressed at the time of analysis. From the several classifications shown in Table V it is evident that the relative age and degree of deterioration as determined from analysis will depend very largely upon which one of the various constituents is selected as the basis of comparison. Similarly, the estimation of age or deterioration from the impressions produced by the aroma will vary according to the individual peculiarities of taste or fancy possessed by the observer. It is much to be regretted that there is not a better understanding of the relations between the factors commonly considered in establishing the relative market value of hops and the actual value of the hops in the processes in which they are utilized. The determination of a definite basis of value from which sound standards could be derived would have great practical importance, both for the producers and for the consumers of hops.

¹ Fischer, A. Modern methods of hop analysis. *Letters on Brewing*, vol. 11, 1912, p. 817.

GENERAL SIGNIFICANCE OF THE RESULTS.

The material which furnished the basis for the observations discussed in this paper was prepared primarily with the view to determining the feasibility of abandoning the practice of sulphuring hops. Some previous experiments had shown¹ that under certain conditions there was some danger of hops becoming slightly contaminated with arsenic during the process of sulphuring, to obviate which the discontinuance of the use of sulphur was naturally suggested. It was expected that the unsulphured hops would be received with less favor by the trade than those which had been sulphured, owing to the more pronounced variations in the color of the former, but at the time the bales of hops selected for observation were placed in storage the difference in general appearance was comparatively small, although the sulphured hops could be readily distinguished by their more uniform and somewhat brighter color. A study of the trade opinions rendered on these hops after they had been for some time in storage apparently shows that the difference in appearance due to sulphuring becomes accentuated with age and that the preference is for the sulphured hop.

When freshly cured, the difference in color between sulphured and unsulphured hops is, as a rule, much more pronounced; and, however careful the grower might be to harvest his crop at the stage of maturity best calculated to give the greatest uniformity in color, it is evident that in marketing his product he would have to seek for those consumers who have a preference for the greenish grades of hops.

From the results of the chemical tests it is apparent that unsulphured hops are less suited to the requirements of the consumer than those that have been sulphured, especially when they are stored for a considerable length of time before they are used. However, the fact should not be lost sight of that these tests were made on hops which had been in storage for more than two years, and the changes observed are certainly considerably greater than those which occur in hops which have been stored for a shorter period. Nevertheless, the greater part of the changes in certain constituents takes place during the first year of storage, as has been shown by Heron² in the case of the tannin of hops. But from the work of Moser,³ who found that the tannin content of unsulphured samples was consistently smaller than that of sulphured samples of the same sorts, it is evident that the oxidation of the tannin is retarded by sulphuring. It may

¹ Stockberger, W. W. The sources of arsenic in certain samples of dried hops. Bulletin 121, pt. 4, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

² Heron, John. The tannin of hops. Journal of the Federated Institutes of Brewing, vol. 2, 1896, p. 172.

³ Cited by Braungart in Der Hopfen, Munich, 1901, p. 849.

be safely assumed, however, that sulphuring is an effective means of retarding chemical changes in hops from the time they are cured until they have reached the desirable limit of age, usually determined by commercial conditions, provided such hops are held in cold storage.

It is fully realized that the conclusions drawn in this paper are subject to the criticism that the analyses are too few in number and that they are not coordinate in point of time with each other and with the physical valuations. Certain obstacles encountered in the course of the work made it impossible to round out the results as fully as was desired, yet it is believed that the coordinations suggested by the facts developed are of sufficient importance to justify this somewhat incomplete presentation, which should be regarded more as a report of progress than as an attempt at a full elucidation of the problem, for which much further experimentation is necessary.

SUMMARY.

Material for a comparative study of the effects of cold and ordinary storage on sulphured and unsulphured hops was secured from a hop field in the Sacramento Valley, Cal. The green hops were divided into two lots, only one of which was sulphured during the process of drying. Bales from each lot were placed in cold and in ordinary storage, and samples from these bales were drawn from time to time for examination with respect to physical condition and certain chemical constituents.

At intervals of 7 and 18 months, respectively, from the time the hops were placed in storage, samples were drawn and submitted to trade experts, who were asked to rate the samples according to their relative quality. All agreed that the sulphured hops in cold storage were best in quality, but opinion was divided as to the relative merit of the three other lots.

Determinations were made of the acidity and ester content of the volatile oils extracted from samples of the hops under each condition of storage. The conclusions drawn from these analyses are that both sulphuring and cold storage retard changes in the hops leading to an increase in acidity and ester content of the oils. Cold storage is apparently more effective than sulphuring in retarding the increase in acidity, but is less efficient than sulphuring in retarding increase in ester content. Cold storage and sulphuring combined are much more effective in retarding changes in acidity and ester content than either alone.

The percentage of decrease in the content of soft resins was less in the cold-stored hops than in those in ordinary storage. The evidence from the analyses goes to show that the sulphuring tends to

retard changes in the content of soft resins only when combined with cold storage.

Trade experts to whom samples of the hops under consideration were submitted for physical judgment differed widely in their opinions of relative merit, except in the case of the sulphured cold-stored hops, which all agreed ranked first. The relative rank in merit as determined from each of the factors sought in analysis was found to give corresponding differences. A comparison of these differences in the physical and chemical valuations shows that the determination of the value of hops from the aroma depends upon the personal taste of the observer and is greatly affected by the individual's preference or dislike of one or the other of the several constituents of the aroma.

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Issued January 21, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 272.

B. T. GALLOWAY, *Chief of Bureau.*

HEREDITY OF A MAIZE VARIATION.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., October 4, 1912.

SIR: I have the honor to transmit herewith a paper entitled "Heredity of a Maize Variation," by Mr. G. N. Collins, Botanist, Crop Acclimatization and Adaptation Investigations, and recommend its publication as Bulletin No. 272 of the series of this Bureau.

Respectfully,

WM. A. TAYLOR,
Acting Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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HEREDITY OF A MAIZE VARIATION.

INTRODUCTION.

A single white ear of maize was discovered in a strain of uniformly yellow corn. The conditions under which the ear appeared and the behavior of its progeny both indicated that its occurrence was in the nature of a direct mutation and not the result of an accidental mixture of seed. The present paper is an account of the heredity of this albinistic ear.

Albinistic mutations are not uncommon in both plants and animals, and many white varieties are supposed to have originated in this way, but so far as known this is the first instance of a mutation of this kind affecting the endosperm of maize. The phenomenon is believed to be of interest, since it suggests one manner in which color diversity in maize may arise.

In maize the endosperm or the starchy portion of the seed exists in two colors, yellow and white. Although this difference in the color of the endosperm or starch may in reality be unimportant, it is, nevertheless, the mark which in the minds of most corn growers distinguishes two great classes of corn. In the corn products prepared for human food the distinction between yellow and white is fundamental and affords a most striking example of the different customs of the North and the South. In the South the use of yellow varieties of corn for human food is almost unknown, while in the North, although white varieties are widely grown, food preparations are made almost entirely from yellow corn.

ENDOSPERM COLOR IN MAIZE.

The popular discrimination between white and yellow varieties of maize for human food is not the result of mere prejudice, for there can be no doubt regarding the difference in taste between the yellow and the white preparations that are on the market. What is not clear is whether the color is necessarily associated with the taste. The characteristic taste of yellow meal, for example, may be due to the choice of varieties, and the color may be only incidental.

In the endosperm of maize the yellow color when present is always confined to the corneous or horny portion of the seed. So far as observed, the soft or starchy endosperm that occupies the center of the grain and which in flour varieties fills practically the entire seed

is always white. The yellow color when present in seeds of a soft variety is therefore confined to the thin outer layer of the translucent or horny endosperm.¹ This definite relation that exists between color and texture makes it appear not improbable that there may in reality be a similar relation between color and taste.

Though the yellow and the white varieties are constantly being mixed, there is little tendency for the color to become intermediate. Very light-yellow seeds are sometimes encountered as a result of xenia in varieties where the yellow is imperfectly dominant, but the endosperm of fixed varieties is either distinctly yellow or pure white.

One source of slight variation in the intensity of the yellow color lies in the varying amount of the horny endosperm to which the yellow color is confined. Thus, in soft varieties, although the thin layer of horny endosperm may be as dark as in horny varieties, the layer is so thin that the general appearance of the seed is comparatively light.

Tracy² has shown that, as a rule, the white varieties are more productive than the yellow. His conclusions are based on averages of all the varieties regarding which data could be obtained, and here again it is not perfectly clear that the color bears any casual relation to the difference in productive power. So far as known, no careful comparisons have been made between the yellow and the white strains of the same variety.

How maize came to be differentiated into yellow and white varieties is shrouded in the mystery that envelops the domestication of the plant. The only suggestion is that of Tracy,³ who advances the idea that white varieties are in the nature of degenerations from the yellow. Both yellow and white varieties are common among the most primitive types of corn that are now being grown in the American Tropics. The remains of prehistoric ears are usually so disintegrated that it is impossible to tell whether the endosperm is yellow or white, but the writer recalls none which did not have either the pericarp or aleurone layer colored.

The inheritance of the endosperm color in maize has been made the subject of comprehensive investigations from the Mendelian point of view. In the exhaustive experiments of East and Hayes⁴ it was shown that in crosses between white and yellow strains the yellow color is dominant to the white in the first xenia generation.

¹ Yellow may also occur in the waxy endosperm of the Chinese corn. See Bulletin 161, Bureau of Plant Industry, U. S. Dept. of Agriculture, entitled "A new type of Indian corn from China."

² Tracy, S. M. The relation of color to yield in corn. Presidential Address at the Thirty-First Annual Meeting of the Society for the Promotion of Agricultural Science, Washington, D. C., Nov. 15, 1910.

³ Op. cit., pp. 12-13.

⁴ East, E. M. A Mendelian interpretation of variation that is apparently continuous. *American Naturalist*, vol. 44, February, 1910, pp. 65-82.

East, E. M., and Hayes, H. K. Inheritance in maize. Bulletin 167, Connecticut Agricultural Experiment Station, April, 1911.

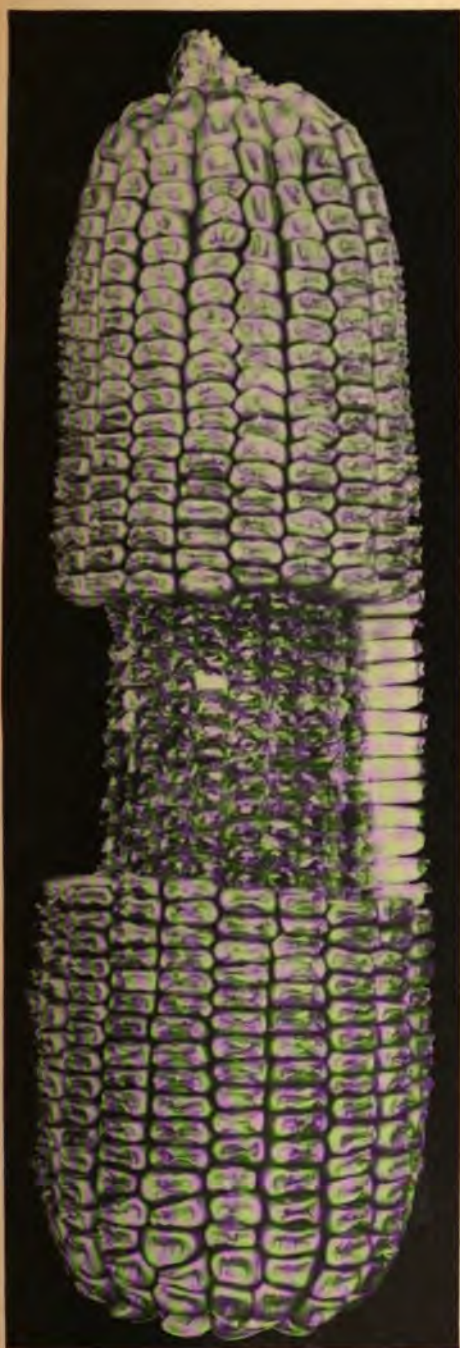


FIG. 1.—A REPRESENTATIVE EAR OF GORHAM YELLOW DENT CORN.

(Natural size.)



FIG. 2.—AN ALBINISTIC MUTATION FROM GORHAM YELLOW DENT CORN.

(Natural size.)

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and that in the next generation the colors usually segregate in a 3 to 1 ratio. In certain crosses reported by these authors, however, the segregation was in the ratio of 15 yellow seeds to 1 white, a ratio explainable on the assumption that there are two factors or ingredients, either one of which will produce the yellow color, and that the factors are independent in inheritance.

DESCRIPTION OF THE MUTATION.

During the corn harvest of 1909 Mr. John Gorham, of Waco, Tex., observed a single white ear of a yellow-dent strain which he had selected carefully for several years. This ear came to the attention of Mr. O. F. Cook, of the Bureau of Plant Industry, who appreciated the interest of such a variation. The possibility that it might represent a mutation was recognized, and an investigation of the case was suggested.

The possibility of chance admixture of seed of a white variety seemed to be excluded, not only by the fact that the variety in which the sport appeared had been carefully selected on the place where it was being grown for a number of years but by the fact that no similar white variety was known in the neighborhood. Moreover, it appeared very strange that an all-white ear could develop in a field of yellow corn. Unless the ear had been entirely self-pollinated there should have been some yellow seeds as a result of xenia. At the same time it was apparent from differences in the shape and size of the ear that the variation did not consist merely in the loss of endosperm color. The most striking difference in form was that the kernels were much shorter than those of the yellow ears.

The Gorham Yellow Dent, the variety in which the mutation occurred, has been developed by Mr. Gorham with the assistance of Mr. D. A. Saunders. A representative ear of this variety is shown in Plate I, figure 1. The color of the seed in this variety is a rich, dark yellow. The variety, though not as uniform as some pedigree cultures, is as constant in its behavior as most commercial varieties. In the examination of the crops and in the selection of seed for six consecutive years no other color variations have been observed by either Mr. Gorham or Mr. Saunders.

A reproduction of a photograph of the white ear is shown in Plate I, figure 2. The ear was fully matured and well filled. In the original variety the cob is red; in the mutation it is pure white. The seed of the mutation, except on the closest examination, would also be considered pure white, but when carefully examined a very faint trace of yellow can be found near the base of most of the seeds. The color is much lighter than any first-generation hybrid of white and yellow that has come under observation.

It was thought that a recently acquired character, such as this colorless endosperm appeared to be, might lack the regularity in behavior that obtains with characters of longer standing and in which the expression tendencies have become more firmly established. The results have shown that the character, while Mendeloid in its inheritance, is not subject to definite and complete segregation.

PROGENY OF THE ALBINISTIC EAR.

FIRST XENIA GENERATION.

It appears probable that the plant which produced the original white ear received pollen from ordinary Gorham plants. If so, the seeds represented the first xenia generation of a cross between white and yellow in which the white was dominant or nearly so. So far as known, this is the first instance of this kind, the yellow endosperm usually being dominant to white.

Owing, perhaps, to a difference in the time of flowering, the seed of the original ear might have been self-pollinated, but in that case the self-pollinated progeny of this ear should have been all white, whereas varying percentages in the progeny showed the full yellow of the Gorham variety, giving further evidence that the ear had been cross-pollinated. It seems more reasonable, however, to associate this reversal of dominance with the appearance of a mutation where abnormal conditions may be expected to prevail rather than to assume that this unusual behavior should occur as a coincidence in connection with a single stray grain that had found its way into the seed planted in 1907. That the failure of dominance was not varietal but was largely confined to the original mutation is shown by the complete dominance of the yellow color in much of the progeny.

Seed from the original mutation was planted in 1910. One self-pollinated ear, No. 930, and two cross-pollinated ears, Nos. 741 and 721, were secured. The seed of these ears represents the second xenia generation.

SECOND XENIA GENERATION.

The self-pollinated ear, No. 930, had both white and yellow seeds, but the presence of a faint-reddish pericarp color made classification rather difficult. The appearance of a pericarp color may also be associated with the mutative change, but in the presence of the full-yellow color of the original variety this character might easily escape detection. In 1911 two hand-pollinated ears were grown from the seed of ear No. 930. One was pure white; the other contained only a few seeds, all of which had yellow endosperm.

Ear No. 741 was a cross between two plants, Nos. 82 and 47, from seed of the original ear. Ear No. 721 was the reciprocal of ear No.

741, that is, plant No. 47 was pollinated by plant No. 82. The progeny of plants Nos. 82 and 47 are shown diagrammatically in figure 1. In both ears the seeds fell naturally into two groups: Dark yellow, like the original Gorham variety, and white or very light yellow seeds. Among both the light and dark-yellow seeds were some with white caps. The white cap appears as a character independent of the color of the body of the seed, but it is difficult to distinguish in the very light-colored seeds and is here left out of consideration.

Of the two classes of seeds the dark yellow was comparatively uniform, and the second group of light-colored seeds was more

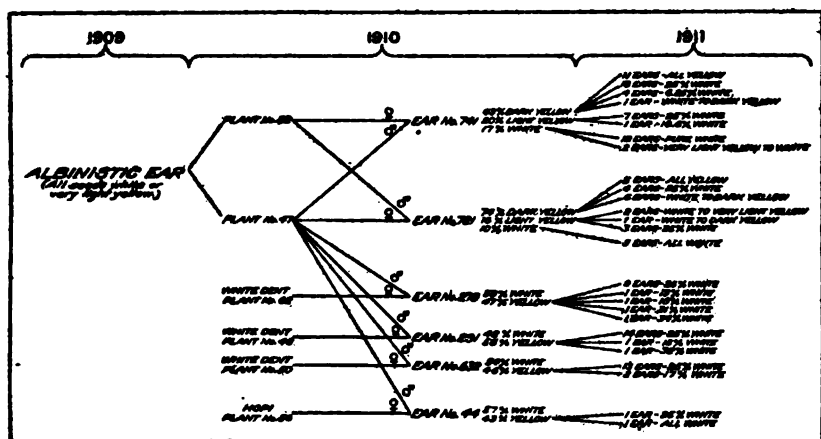


FIG. 1.—Diagram showing the inheritance of endosperm color in the progeny of an albinistic ear of corn.

variable. It was even possible further to divide the second group into white and light-yellow seeds with some degree of positiveness. Table I shows the number of seeds in the different classes.

TABLE I.—Classification showing the number of seeds by endosperm colors in the second zenia generation.

Ear No.	Total number of seeds.	Dark-yellow seeds.	Light-yellow seeds.	White seeds.
721.....	502	436	96	60
741.....	515	327	108	85
Total.....	1,107	763	199	145

Considering first the two obvious classes, dark-yellow as contrasted with the light-yellow and the white seeds, and comparing their numbers with the 3 to 1 ratio of a monohybrid, the results are shown in Table II.

TABLE II.—*Number of white seeds of the second xenia generation compared with the monohybrid ratio.*

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 3 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
721.....	592	156	148 ± 7.1	+ 8	1.1	26.3
741.....	515	188	129 ± 6.6	+59	8.9	36.5
Total.....	1,107	344	277 ± 10	+67	6.7	31.1

Ear No. 721 agrees as well as could be expected with the monohybrid ratio. The reciprocal ear, No. 741, approaches more nearly the 7 to 9 ratio of a dihybrid, but from this ratio it deviates nearly five times the probable error. It is not uncommon for reciprocals to differ in endosperm color, the female parent usually exerting the greater influence. This prepotency of the female usually shows itself, however, in the intensity of the color and not, as here, in different numerical relations. No differences in the intensity of the color of the two ears were apparent.

This deviation from the normal 3 to 1 ratio is the more interesting, since the progeny of the heterozygous seeds from both these ears, which are later discussed, exhibit the same classes of dark and light yellow or white seeds, and in nearly every ear the numbers are in the ratio of 3 to 1.

Regarding the less obvious distinction between the pure-white and light-yellow seeds in these ears, it will be seen that ear No. 721 had 10.1 per cent and ear No. 741 had 16.5 per cent of the total number of seeds classed as pure white. In neither case can the ratio be referred to either the monohybrid or dihybrid ratios, which are 25 per cent and 6.25 per cent, respectively. The numbers would be approximated if we assume that one of the parent plants was heterozygous for both of two factors, either one of which would produce yellow, and that the other parent possessed only one of these factors. The expected percentage of white seeds would then be 7 to 1, or 12.5 per cent. Considered from this viewpoint the observed number shows the approximations given in Table III.

TABLE III.—*Number of pure-white seeds of the second xenia generation compared with a 7 to 1 ratio.*

Ear No.	Total number of seeds.	Number of pure-white seeds.	Expected number of white seeds on a 7 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
721.....	592	60	74 ± 5.4	-14	2.6	10.1
741.....	515	85	64 ± 5.1	+21	4.1	16.5
Total.....	1,107	145	138 ± 7.4	+ 7	.9	13.1

It should be remarked, in connection with the excess of white seeds in ear No. 741, that out of 14 self-pollinated ears grown from the white seeds of this ear the following season 2 showed light-yellow seeds. If this ratio held, and approximately 2 out of every 14 of the ears classed as white are in reality very light yellow, the number of pure-white seeds would be reduced to 73, a deviation from the expected number of 9, or only 1.8 times the probable error.

THIRD XENIA GENERATION.

In the following year, 1911, 84 self-pollinated ears were secured from seed of the 2 reciprocal ears, Nos. 721 and 741. Sixty-four of these self-pollinated ears were from colored seeds. From the ratios secured in the second xenia generation it was suggested that one of the parents of these two ears might be heterozygous for one yellow factor, with the other factor absent, while the other parent was heterozygous for both factors. If this were true, the self-pollinated ears raised from the yellow seeds should have been colored as follows: Eighteen all yellow, 27 with 25 per cent of white seeds, and 18 with 6.25 per cent of white seeds.

In reality 15 ears were found with the seeds all yellow, 30 ears with approximately 25 per cent of white seeds, 4 ears that approximated 6.25 per cent of white seeds, and 15 ears in which the classes were either poorly marked or the number of white seeds were not referable to any expected ratio. Thus, the number of ears that were all yellow and those that had 25 per cent of the seeds white are seen to be in close accord with the expected ratios.

While in most cases the distinction between the white and yellow seeds was perfectly obvious, it did not require close scrutiny to see that the seeds placed in the white class were not uniformly pure white. This phenomenon is further discussed when the details of the different ears are given.

PROGENY OF EAR NO. 741.

Ear No. 741, which resulted from crossing 2 plants from seed of the original albinistic ear, had 515 seeds that were classified as white, light yellow, and dark yellow. Each class was planted separately in 1911.

White seeds.—Fourteen self-pollinated ears from the white seeds of No. 741 gave 12 pure-white ears; the remaining 2 ears, Nos. 770 and 779, were at first passed for white, but a close examination showed some seed with a distinct yellow tinge and many with an appreciable trace of yellow. An attempt was made to classify ear No. 779, which resulted in 368 white seeds and 128 seeds in which a trace of yellow could be seen. The classification was, however, more or less arbitrary.

Light-yellow seeds.—From the light-yellow seeds of ear No. 741, ten self-pollinated ears were secured. In two of these ears the endosperm color was obscured by a colored pericarp, and no attempt was made to classify the seed, though it could be seen that both yellow and white endosperm were represented. Of the eight remaining ears, seven showed light-yellow and white seeds in the proportion of three yellow to one white. The greatest deviation in any of the seven ears was only 2.3 times the probable error, and of the seven ears three deviated less and four more than the probable error. The total number of seeds from the seven ears was 3,193, of which 812 were white, the expected number being 798 ± 16.5 , a deviation of 14 seeds, or 0.85 of the probable error.

In the remaining ear, No. 815, though also possessed of a light pericarp color, the seeds could be readily classified. The total number of seeds in this ear was 388, of which 72, or 18.6 per cent, were white. No. 815 was the only ear grown from the light-yellow seed that produced yellow seeds as dark as the yellow of the original Gorham variety. In the others the color resembled the immediate parent seed in intensity.

Dark-yellow seeds.—From the dark-yellow seeds of ear No. 741, thirty-four self-pollinated ears were secured. These were readily classified into the following groups: Eleven all-yellow ears of varying shades; 18 yellow and white ears, approximating a 3 to 1 ratio; 4 yellow and white ears, approximating a 15 to 1 ratio; and 1 ear with seeds of all shades from white to dark yellow.

The 18 ears referred to the 3 to 1 ratio are all in close agreement with the expected numbers. The total number of seeds for the 18 ears was 9,004, of which 2,281 were white, a deviation of 29 from the expected number, 2,252. There were 11 plus and 6 minus deviations. In 8 of the ears the deviation was less than the probable error; the widest deviation was 3.7 times the probable error. In every ear referred to this group the classes were well marked. In 10 of the 18 ears, however, the white class contained seeds in which a trace of yellow could be made out, but in none was there any evidence of discontinuity within the class.

In the group of four ears referred to the 15 to 1 ratio there was also an obvious gap between the dark and light-yellow seeds, though the distinction was not as pronounced as in the first group. But in these ears it was possible to separate the light seeds into light yellow and pure white with some degree of certainty, and it is this class of pure-white seeds that approximates the 6.25 per cent, or 1 to 15 ratio. The numbers for the four ears referred to this group are shown in Table IV.

TABLE IV.—*Number of seeds by seed classes in third xenia generation compared with the dihybrid ratio.*

Ear No.	Total number of seeds.	Number of light-yellow seeds.	Number of white seeds.	Expected number of white seeds on a 15 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
790.....	741	143	47	46±4.4	+ 1	0.2	6.3
791.....	557	122	17	35±3.8	-18	4.7	3.1
797.....	770	131	56	49±4.5	+ 8	1.8	7.2
802.....	657	112	57	41±4.2	+16	3.8	8.7
Total.....	2,725	497	177	170±8.5	+ 7	.8	6.5

In Table V the white and the light-yellow seeds are considered as one class contrasted with the dark-yellow seeds, and the numbers are compared with a 3 to 1 ratio.

TABLE V.—*Number of seeds by seed classes in third xenia generation compared with the monohybrid ratio.*

Ear No.	Total number of seeds.	Number of white and light-yellow seeds.	Expected number on a 3 to 1 ratio.	Deviation from expected number of white and light-yellow seeds.	Deviation divided by probable error.	Percentage of white and light-yellow seeds.
790.....	741	180	185± 7.9	+ 4	0.5	25.5
791.....	557	130	139± 6.9	0.0	.0	25.0
797.....	770	177	163± 8.1	-16	2.0	23.0
802.....	657	160	164± 7.5	+ 5	.7	25.7
Total.....	2,725	674	681±15.2	- 7	.5	24.7

Too much significance should not be attached to the ratios represented by the pure-white seeds in these four ears, though the closeness to 6.25 per cent, which is the expected percentage where two factors are involved, is suggestive. In nearly every ear the classification was more or less arbitrary. Granted that subsequent generations show that 6.25 per cent of the seeds fail to produce yellow, rather violent assumptions are necessary to account for the definite class representing 25 per cent of the total number. It would be necessary to assume that the two factors for yellow show very different potencies, so that one of them, although received from both parents, produces a much lighter yellow than where the other factor is received from only one parent. In Mendelian terminology one of the factors, "Y," for example, must be assumed to be much less effective than "Y₁", so that the classes yyy₁y₁, Yyy₁y₁, and YYy₁y₁ will be either white or very light yellow, while all other combinations are dark yellow.

Although the 25 per cent ratio is that of a simple Mendelian character, it can not be explained as such, since the recessive class

may be expected, as in the previous generation, to produce both yellow and white. A less complicated way of looking at these results is to admit the incompleteness of segregation, the group of 25 per cent representing the class in which the character fails to come into expression except in an incomplete way.

PROGENY OF EAR NO. 721.

The seeds of ear No. 721, the reciprocal of ear No. 741, were in like manner classified into white, light yellow, and dark yellow, and each planted separately. The results were in general similar to those secured from ear No. 741, except that in none of the ears could the light seeds be separated into light yellow and pure white with any degree of certainty.

White seeds.—Five self-pollinated ears were secured from the white seeds of ear No. 721. All were pure white.

Light-yellow seeds.—From the seeds that were light yellow six self-pollinated ears were obtained. Two of these ears would be passed for pure white except on very close inspection, when a trace of yellow could be made out in many of the seeds. No attempt was made to classify these ears. The classes in the remaining four ears are shown in Table VI, where the results are compared with those expected if the character was segregating as a monohybrid.

TABLE VI.—*Number of seeds, by seed classes, in third xenia generation compared with the monohybrid ratio.*

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 3 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
760.....	790	213	198±8.2	+ 51	1.8	27.0
763.....	585	280	146±7.1	+134	18.8	47.9
764.....	559	131	140±6.9	- 9	1.3	23.4
766.....	69	20	17±2.4	+ 3	1.2	29.0

The foregoing classification was that into which the seeds could be most naturally divided, though the classes were only moderately well marked. In each ear it could be seen that some of the seeds classed as white contained minute traces of yellow. No special significance should be attached to the large number of white seeds in ear No. 763. The classes in this ear were very poorly defined, the gradations in color forming almost a continuous series from white to dark yellow.

Dark-yellow seeds.—From the dark-yellow seeds of ear No. 721 15 self-pollinated ears were secured, as follows: 5 with all-yellow seeds of varying shades; 4 with yellow and white seeds, approximating a 3 to 1 ratio; and 6 with seeds of all shades from white to dark yellow.

The 4 ears which showed classes that were distinctly marked all approximated very closely the 3 to 1 ratio. The total number of seeds

was 2,644, of which 673 were white, a deviation of only 12 from the expected 661 seeds. But in 3 of the 4 ears faint traces of yellow were apparent in seeds of the white class.

Considering the progeny of all the yellow seeds from ears Nos. 741 and 721 regardless of the intensity of the color, it appears that in every ear in which the classes were well marked the white class represented approximately 25 per cent of the total number of seeds.

In many of the ears the seeds classed as white were not pure white, and in a few ears these light seeds can be further divided into very light yellow and pure white, the latter class representing approximately 6.25 per cent of the total number of seeds. It will thus be seen that while the results from self-pollinating the second-generation plants are generally in numerical accord with the Mendelian expectation, segregation is apparently incomplete.

These results are in striking contrast with the behavior of the endosperm texture observed in hybrids between varieties with the ordinary endosperm and a Chinese variety with a waxy endosperm. In the latter crosses segregation of endosperm texture appeared complete, but numerical deviations from the expected ratios were of common occurrence.¹

The appearance of classes representing both 6.25 per cent and 25 per cent of the total number of seeds would be in accord with the hypothesis that two factors were involved, were it not that both ratios occur in the same ear.

CROSS OF THE ALBINISTIC EAR WITH A WHITE DENT VARIETY.

It was suggested that the ratios observed in ears Nos. 721 and 741 of the second generation might be explained on the assumption that one of the parents of these reciprocal ears was heterozygous for two factors, the other parent possessing but one factor and this in a heterozygous condition.

If one of the parents of ears Nos. 721 and 741 was producing yellow and white gametes in equal numbers, it was undoubtedly plant No. 47, as shown by the results given below.

FIRST GENERATION.

Plant No. 47 was used to pollinate 3 ears of A4, a pure-white strain continuously pure seeded for three years. If plant No. 47 was producing yellow and white gametes in equal numbers these ears should have equal numbers of yellow and of white seeds. The results are shown in Table VII. (See also fig. 1.)

¹ Collins, G. N., and Kempton, J. H. Inheritance of waxy endosperm in hybrids of Chinese maize. Quatrième Conférence Internationale de Génétique, Paris, 1912, pp. 347-357.

TABLE VII.—*Number of white seeds of first xenia generation compared with a 1 to 1 ratio.*

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 1 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
278.....	268	154	144±5.7	+10	1.8	53.5
291.....	130	50	60±3.7	-10	2.7	41.6
632.....	154	83	77±4.2	+ 6	1.4	53.9
Total.....	552	287	281±8.0	+ 6	.8	51.1

These results are thus seen to bear out the assumption that plant No. 47 was heterozygous for only one factor. In the next generation, however, irregularities occurred.

SECOND GENERATION.

Progeny of ear No. 278.—Yellow seeds from ear No. 278 were planted in 1911 and 13 self-pollinated ears secured. All showed both yellow and white seeds, and with four exceptions the ratio might be referred to the expected 25 per cent. The total number of seeds was 4,867. The number expected to be white (one-fourth of the total) was $1,217 \pm 20.3$. The actual number of white seeds was 1,158, a deviation of 59 seeds, 2.9 times the probable error. The results are shown in Table VIII.

TABLE VIII.—*Number of white seeds in the progeny of ear No. 278 compared with the monohybrid ratio.*

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 3 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
284.....	263	65	66± 4.7	- 1	0.2	24.7
289.....	101	24	25± 2.9	- 1	.3	23.8
716.....	107	27	26± 3.0	+ 1	.3	25.2
280.....	607	146	152± 7.2	- 6	.8	24.1
288.....	91	20	23± 2.8	- 3	1.1	22.0
279.....	705	164	176± 7.7	-12	1.6	23.3
281.....	585	158	146± 7.1	+12	1.7	27.0
717.....	367	80	92± 5.6	-12	2.1	21.8
286.....	370	105	92± 5.6	+13	2.3	28.4
*285.....	451	147	120± 6.4	+27	4.2	30.6
*287.....	185	64	46± 4.0	+18	4.5	34.6
*283.....	454	83	114± 6.2	-31	5.0	18.3
*282.....	551	75	138± 6.8	-63	9.3	13.6
Total.....	4,867	1,158	1,217±20.3	-59	2.9	23.8

* Exception referred to.

In all of these ears the number of seeds is large enough to make the deviations significant. In ears Nos. 282 and 283 the classes were not well marked, but both showed an excess of yellow seeds, and only those seeds in which the color was unmistakable were classed as yellow. In ears Nos. 285 and 287 the classes were well marked.

Progeny of ear No. 291.—Sixteen self-pollinated ears were secured from the yellow seeds of ear No. 291. Again, all showed both yellow and white seeds, all but two of which may be referred to the 3 to 1 ratio.

The total number of seeds was 8,007. The total number of white seeds was 2,012, where $2,002 \pm 26.1$ were expected, a deviation of 10 seeds. The results are shown in Table IX.

TABLE IX.—Number of white seeds in the progeny of ear No. 291 compared with the monohybrid ratio.

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 3 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
674.....	785	189	191 ± 8.1	- 2	0.2	24.7
675.....	692	170	173 ± 7.7	- 3	.4	24.6
683.....	396	96	99 ± 5.8	- 3	.5	24.2
297.....	467	120	117 ± 6.3	+ 3	.5	25.7
294.....	616	158	154 ± 7.3	+ 4	.5	25.6
295.....	403	97	101 ± 5.9	- 4	.7	24.0
292.....	662	175	166 ± 7.5	+ 9	1.2	26.4
679.....	422	97	108 ± 6.0	- 8	1.3	23.0
678.....	633	146	158 ± 7.3	-12	1.6	23.1
677.....	644	148	161 ± 7.4	-13	1.8	23.0
681.....	262	75	86 ± 4.7	+ 9	1.9	28.6
293.....	665	182	166 ± 7.5	+16	2.1	27.4
684.....	299	80	87 ± 4.8	+13	2.7	29.7
685.....	83	31	21 ± 2.7	+10	3.7	37.3
*676.....	555	177	139 ± 6.9	+38	5.5	31.9
*680.....	473	71	118 ± 6.4	-47	7.4	15.0
Total.....	8,007	2,012	$2,002 \pm 26.1$	10	.4	25.1

* Exception referred to.

In this family, as in the preceding, while the original assumption is borne out by most of the ears, the exceptions can not reasonably be ascribed to chance.

In both the variant ears the classes are beautifully distinct, but in ear No. 680 some of the white seeds may contain a trace of yellow.

In ear No. 685 the percentage of white seeds is high, but the number of seeds is so small that the deviation may easily be due to chance.

Progeny of ear No. 632.—Fifteen self-pollinated ears were secured from yellow seeds of ear No. 632. Of these all except three ears approximated the expected 25 per cent white. The results are shown in Table X. The total number of seeds in the 15 ears was 8,661, of which 2,014 were white. The expected number of white seeds was $2,165 \pm 27.2$, a deviation of 151 seeds, or 5.6 times the probable error.

TABLE X.—*Number of white seeds in the progeny of ear No. 632 compared with the monohybrid ratio.*

Ear No.	Total number of seeds.	Number of white seeds.	Expected number of white seeds on a 3 to 1 ratio.	Deviation from expected number of white seeds.	Deviation divided by probable error.	Percentage of white seeds.
666.....	517	128	129 ± 6.6	— 1	0.2	24.8
666.....	472	119	118 ± 6.3	+ 1	.2	25.2
669.....	735	186	184 ± 7.9	+ 2	.3	25.3
669.....	565	144	141 ± 6.9	+ 3	.4	26.5
666.....	515	124	129 ± 6.6	— 5	.8	24.1
667.....	751	181	188 ± 8.0	— 7	.9	24.1
672.....	577	150	144 ± 7.0	+ 6	.9	26.0
658.....	541	144	135 ± 6.8	+ 9	1.3	26.6
655.....	585	159	146 ± 7.1	+ 13	1.8	27.2
668.....	562	127	140 ± 6.9	— 13	1.9	22.6
671.....	609	128	152 ± 7.2	— 14	1.9	22.7
673.....	453	95	113 ± 6.2	— 18	2.9	21.0
*667.....	537	108	134 ± 6.8	— 26	3.8	20.1
*654.....	622	106	155 ± 7.3	— 49	6.7	17.1
*670.....	620	105	155 ± 7.3	— 50	6.9	16.9
Total.....	8,661	2,014	2,166 ± 27.2	—151	5.6	23.2

* Exception referred to.

Excluding the 3 ears which do not approximate the 3 to 1 ratio, the deviation is only 25 seeds, with a probable error of 24.2.

The total progeny of the 3 ears, Nos. 278, 291, and 632, consisted of 44 ears with 21,535 seeds; of these 5,184 were white. If behaving as a simple character we should have expected $5,384 \pm 43$ white seeds. Thus there is a deviation of 200 seeds, or 4.7 times the probable error. But this deviation results from the behavior of a comparatively few aberrant ears and not from a general tendency, or skew, such as was found with the inheritance of the endosperm texture.¹

CROSS OF THE ALBINISTIC EAR WITH THE HOPI VARIETY.

In 1909 pollen from plant No. 47, the same plant that was used as the male parent in the crosses referred to in Table I, was used on a plant of the Hopi white-seeded variety, producing an ear, No. 44, having 249 white and 191 yellow seeds, with the classes very well marked. The expected number of white seeds on a 1 to 1 ratio is 220 ± 7.1 . There is thus a deviation of 4.1 times the probable error. It may be noted that the expected number of seeds on a 7 to 9 ratio is 193, but to judge from the behavior of this color elsewhere the larger class should have been the yellow instead of the white.

Three selfed ears from the yellow seeds of ear No. 44 gave in 1911 1 poorly developed yellow-and-white ear, 1 ear with 188 white and 565 yellow seeds, and 1 pure-white ear.

The appearance of a pure-white self-pollinated ear from a yellow seed must be taken as an example of complete reversal of dominance

¹ Collins, G. N., and Kempton, J. H. Inheritance of waxy endosperm in hybrids of Chinese maize. Quatrième Conférence Internationale de Génétique, Paris, 1912.

in the parent seed or the complete loss of a Mendelian character, perhaps in the same way that endosperm color was lost in the original albinistic mutation. With the idea that the alternative characters are a function of expression it is to be expected that yellow may again appear in the progeny of this ear. The seed for the 1911 experiment was planted by the writer, and the classes of the original ear are so well marked that the chance planting of a white seed among the yellow seeds is very improbable. The progeny of this pure-white ear will be carefully watched for the appearance of yellow. The ear is well filled and fully matured and the closest scrutiny fails to disclose the least trace of yellow endosperm.¹

DISCUSSION OF RESULTS.

Viewed in a general way it can be said that pure-seed progenies of the albinistic ear have resulted in all shades of yellow from the merest trace to the fully developed orange of the variety from which the mutation originated. The pronounced tendency for the seeds to fall into two groups representing 25 per cent and 75 per cent of the total number shows that the inheritance is Mendeloid, though not definitely alternative. The grouping into classes representing 25 per cent and 75 per cent suggests that a single character with somewhat variable dominance is involved, but on this assumption the segregation must be held to be incomplete, since the recessive class shows definite traces of yellow.

The appearance in some of the ears of a class apparently pure white, representing approximately 6.25 per cent, suggests that two factors are involved. But if two factors are involved, the definite class representing 25 per cent of the seed in the same ears that show the pure-white class of 6.25 per cent can be explained on the factor hypothesis only by elaborate and unwarranted assumptions.

The small class constituting 6.25 per cent also argues against the presence of more than two factors. For if three or more factors are involved the same violent assumptions are required to accommodate the 6.25 per cent ratio that are required to accommodate the 25 per cent ratio with two factors.

The definiteness with which the two classes represent 25 and 75 per cent is merely an addition to the large mass of evidence already on record with respect to a great variety of plants and animals, to the effect that alternative characters tend to segregate in equal numbers.

The more significant fact from the theoretical point of view is that while the segregation is usually numerically exact, it is by no means

¹ Since this bulletin was sent forward for publication the 1912 crop has been harvested. Nine self-pollinated ears from the seed of this pure white ear were secured. Five of these are pure white. All of the others have some seeds that are unmistakably yellow, though the color is faint.

complete; that is, the dominant character, yellow endosperm in this case, is not completely absent from individuals of the recessive class. This is shown not only by the presence of a faint-yellow color in most of the seeds, but also by the fact that apparently pure-white seeds from an ear in which the classes were well marked may produce seed with a fully developed yellow color when self-pollinated.

The results appear as evidence against the idea of gametic purity and alternative inheritance, but are rather in accord with the modifications of the Mendelian theory that have been advanced by Castle,¹ Reid,² Cook,³ and others. These authors, while holding diverse views in many particulars, all agree that segregation is incomplete in the sense that the extracted dominants and recessives transmit traces of the alternative character in more or less latent form.

The mathematical regularity exhibited in the expression of most alternative characters is so striking and attractive that careful comparisons between the original and extracted types are often overlooked. There may have been a tendency to assume that if the characters segregated in accordance with an expected ratio the segregates were necessarily pure. The numerous examples where this has now been shown not to be the case should call for a careful re-examination of the classes in the various Mendelian experiments with this point in mind. That large numbers of individuals bred from the extracted types fail to bring the alternative characters into full expression can no longer be taken to prove that the types are "pure."

CONCLUSIONS.

The present paper is a study of the inheritance of one of the endosperm characters of maize in the progeny of an albinistic mutation. The results are of interest in relation to one of the general problems of heredity—the segregation of characters in the offspring of hybrids.

It has been assumed that alternative characters when brought together in hybrids will separate and reappear in pure form, unchanged by the temporary union. The endosperm characters of maize afford excellent material for the study of this question and have played an important part in establishing the theory of complete segregation. The numerical regularity with which many characters reappear in the later generations of a hybrid is one of the chief arguments for the theory of segregation or alternative transmission.

The results here reported of the inheritance of an albinistic variation seem to demonstrate that in this instance, while the original

¹ Castle, W. E. The inconstancy of unit characters. *American Naturalist*, vol. 46, no. 546, June, 1912, p. 351.

² Reid, G. A. O'B. *The Laws of Heredity*, London, 1910, pp. 159-163.

³ Cook, O. F. Transmission inheritance distinct from expression inheritance. *Science*, n. s., vol. 26, June 7, 1907.

characters reappear, they are not the same; in other words, the segregation is not complete.

Previous experimenters in this field have found the endosperm color somewhat refractory as an example of the segregation theory, but by subdividing the character into factors it has been possible to bring their results into conformity with the theory. The results here reported do not lend themselves to such an explanation.

The study is based on the progeny of a white ear that appeared in a carefully selected yellow variety. The circumstances under which the variation appeared, as well as the behavior of the progeny, show that the occurrence of this white ear can not be ascribed to the accidental admixture of seed but must have arisen as an abrupt mutative change of characters.

In the original mutation the white color was almost completely dominant over the yellow. In subsequent generations, however, the yellow reappeared as a dominant character, though variable in intensity. The results accord numerically with the Mendelian expectation, but the recessive white seeds instead of being pure show minute traces of yellow.

Imperfect segregation must be taken into consideration as an obstacle to securing combinations of characters by hybridizing. The occurrence of Mendelian ratios can not be taken as conclusive evidence that subsequent selection will not be necessary to establish the full expression of characters.

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FIG. 1.—HARVESTING ROTUNDIFOLIA GRAPES BY THE JARRING METHOD AT THE MEDOC VINEYARD, NEAR ENFIELD, N. C.

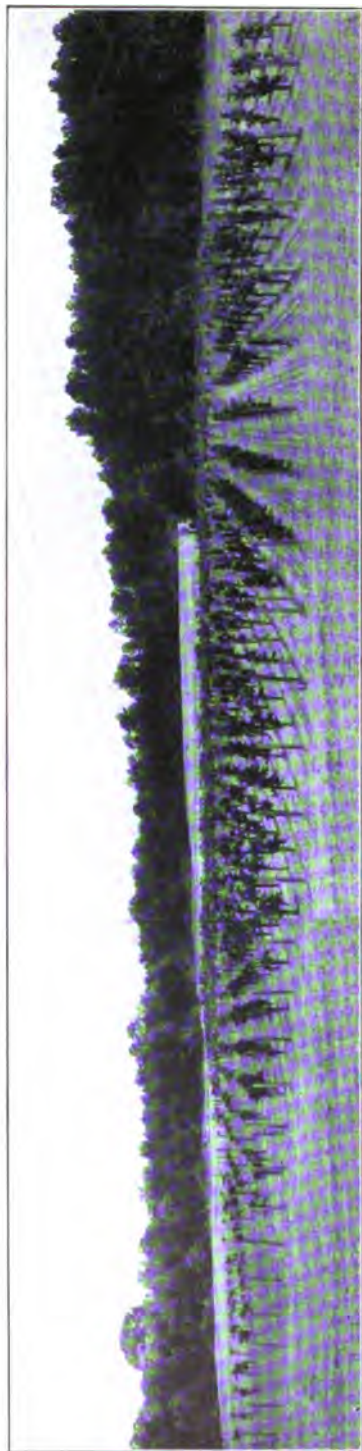


FIG. 2.—GENERAL VIEW OF BLOCKS 1 AND 2 OF THE ROTUNDIFOLIA EXPERIMENT VINEYARD AT WILLARD, N. C.

Issued May 5, 1913.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 273.
B. T. GALLOWAY, *Chief of Bureau.*

THE MUSCADINE GRAPES.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE,
1913,

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, BEVERLY T. GALLOWAY.
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., July 13, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "The Muscadine Grapes" and to recommend that it be published as Bulletin No. 273 of the series of this Bureau. This bulletin has been prepared by Mr. George C. Husmann, Pomologist in Charge of Viticultural Investigations, assisted by Mr. Charles Dearing, Scientific Assistant, and was submitted by Mr. A. V. Stubenrauch, Pomologist in Charge of Field Investigations in Pomology, with a view to its publication.

This bulletin brings together comprehensive information and data regarding the Muscadine-grape industry, giving also an outline of cooperative experimental work in progress on the Pender Test Farm of the Department of Agriculture of North Carolina, and the information presented is thought to be of fundamental importance to those interested in the culture of this fruit. This industry is assuming important proportions, and the investigations have in view the determination of the factors underlying the improvement of cultural conditions and methods of disposing of the crops.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE MUSCADINE GRAPES.

INTRODUCTION.

During the last decade a general industrial and agricultural awakening has been in progress in the South Atlantic and Gulf States. Rapid advancement has been made along many lines. Commercial and manufacturing industries are making their appearance on all sides and great strides have also been made in agricultural development. The existing labor and other conditions render urgent the development of more varied agricultural pursuits and also demand that other lines besides those commonly followed be taken up. The destruction of the forests as a result of the turpentine and lumber industries calls for the utilization of the denuded lands, and there is thus abundant opportunity for agricultural undertakings.

The horticultural development of this, as of all other sections, depends to a very great extent upon the native fruits of the region. The South is rich in native fruits, but even among the most important of these none are more promising, none will adjust themselves so well to the diverse conditions, none will yield fruit for which there are so many uses or for which such large returns for time and means expended are received as the Muscadine grapes.

The purpose of this bulletin is to give some glimpses of the past and present condition of the Muscadine grape industry, to call attention to some of its possibilities, and to indicate the important problems in the industry that require solution. It is intended as a report of the viticultural investigations of the Bureau of Plant Industry in Muscadine regions from 1905 to 1911, including both a discussion of the results already accomplished and a description of the important researches that are under way.

PRESENT STATUS OF THE MUSCADINE-GRAPE INDUSTRY.

That part of the United States in which the Muscadine grapes are native and where soil, climatic, and other conditions suited to them are found embraces an area of not less than 400,000 square miles, or more than 250,000,000 acres, a large portion of which is now unused. This district includes the entire southeastern Coastal Plain from the James River to Florida, reaching well up into the Blue Ridge Moun-

tains; from Florida it extends along the Gulf coast to the Rio Grande, and also northward along the Mississippi River to southeastern Missouri and the Tennessee River.

A preliminary survey of the Muscadine grape industry shows that, while it is more advanced in some places than in others, it is as yet comparatively undeveloped. The commercial varieties have been slightly distributed, but the adaptability of varieties to varying soil, climatic, and other conditions has not been studied, nor has the relative value of different varieties for particular uses been determined. The best known systems of growing and training the vines are of the crudest nature. Aside from a very few large commercial vineyards where the product is made into wine and in which more advanced methods are gradually being introduced, the growing of Muscadine grapes has been largely for home use and limited to local trade. We also find that of all grape species the Muscadinia are the most resistant to *Phylloxera vastatrix*, or root louse, which is so destructive to the Vinifera species. They are also apparently less subject to the various fungous diseases so troublesome to other species when planted in the Muscadine region. They are able to adapt themselves to many different environments and yield good results with practically no care.

The investigators of the Department of Agriculture have long appreciated the many possibilities of this group of grapes under southern conditions. In 1905 a series of investigations was begun with the object of encouraging the planting of the vines and also in order to assist in developing a large and profitable industry. These investigations were started by and are still being continued under the direction of the senior writer of this bulletin, who was assisted from August, 1905, to March 1, 1908, by Mr. E. F. Cole, scientific assistant, and since March 1, 1910, by the junior writer.

Extensive field surveys have been made in order to study the species in their native habitat and to make a close botanical and viticultural investigation of the species; to trace the history of the few cultivated and better known varieties and locate others of merit; to study the relation of varieties to soils in which and the conditions under which they thrive best; to assemble and grow for observation, study, and comparison, the varieties located; to devise better methods of culture and of supporting and training *Rotundifolia*; to ascertain the value of the fruit for diverse purposes, and to improve on the methods of marketing and preserving it.

THE COOPERATIVE ROTUNDIFOLIA EXPERIMENT VINEYARD.

In 1907 arrangements were completed for the establishment of a cooperative experiment vineyard of 15 acres located on the Pender test farm of the North Carolina State Board of Agriculture at Wil-

ard, N. C., and an agreement was made with the board relative to the maintenance and care of the plat.

In 1908, 60 plants each of the 6 leading commercial *Rotundifolia* varieties were planted in regular checks for the purpose of testing diverse methods of pruning and training, while 779 seedlings of *Rotundifolia* and *Rotundifolia* hybrids grown from seed at the Arlington Farm were also planted for observation and study. (Pl. I., fig. 2.) With a view to procuring plants of promising *Rotundifolia* and *Munsoniana* varieties, heretofore located in field surveys, to grow these for observation, comparison, and study, and to determine the feasibility of propagating such varieties from cuttings, cuttings of 44 varieties procured from different persons were planted in the nursery.

In 1909 plantings in a varietal collection vineyard were commenced from plants of varieties grown in the nursery, and 23 varieties have been planted in regular checks to be grown for comparison and study. From seed obtained through previous pollinating work, 1,030 seedlings were grown and planted on the Pender farm for observation and study, adjoining previous plantings from a similar source.

In 1910 trellises and arbors were erected in the *Rotundifolia* experiment vineyard, on which to train the vines of the six standard *Rotundifolia* varieties in regular checks, and a series of pruning and training experiments was undertaken in order to improve on the crude methods followed in commercial vineyards and to determine the system best suited to *Rotundifolia* vines. Thirty additional varieties were planted in the varietal collection vineyard. On account of the exceedingly wet weather that prevailed during July and August, 1910, and the poor drainage of the land, these were not very successful.

There are 952 of the seedlings planted in the spring of 1908 and 1909 alive and growing under test. Of these, 570 are straight *Rotundifolia* crosses, of which 290, or 39.1 per cent, have bloomed, 98, or 33.7 per cent, of these being pistillate. In a score made of the vines as to vigor, that of the female vines was 90.66 per cent and of the male vines 89.3 per cent.

In 1911 additional plantings of 108 vines of standard varieties and 34 vines of newer varieties were made. Comprehensive propagation experiments were started. Cuttings of new natural varieties located in field surveys, of standard varieties, and of promising seedlings in the breeding block were assembled and planted in the nursery. Bench grafts to the number of 250, 114 field grafts, and a number of layers were made. Extensive experiments were conducted in the spring as a continuation of the pollination and breeding studies of *Muscadine* grapes, and the keeping of phenological notes was also begun.

**BOTANICAL RELATION AND CLASSIFICATION OF THE
MUSCADINIA.**

All grapes belong to the genus *Vitis*, or that portion of the large family of plants known as the Vitaceæ or vine family which has naked-tipped tendrils and edible, pulpy berries. This genus is divided into two groups, the *Euvtis* and the *Muscadinia*. The varieties of the *Euvtis* group have loose, shreddy bark, forked tendrils, solid nodes, pith not continuous, and wrinkled seeds neither flat nor transverse. To this group belong all the species of *Vitis* except the *Rotundifolia* and the *Munsoniana*, which form the *Muscadinia* group, having the bark closely adherent on the young branches, the pith continuous through the nodes, the tendrils single, and the seeds flattened, with transverse wrinkles on the sides. The *Rotundifolia* have large berries with large seeds and the *Munsoniana* have small berries with small seeds. (Pl. II, fig. 1.) Besides the distinct characteristics mentioned the *Muscadinia*, commonly called "Muscadine grapes," are sometimes called "berry grapes" on account of the tendency of the individual berries of most of the varieties to shell and fall from the bunch as they ripen, whereas most varieties of the species belonging to the *Euvtis* group, often called "bunch grapes," ripen in clusters and are harvested as such.

VITIS ROTUNDIFOLIA.

Vitis rotundifolia is by far the more important of the two *Muscadinia* species, because all the prominent cultivated varieties belong to it. *Rotundifolia* vines are found wild in the woods and swamps, along rivers and roadsides, and in fence corners throughout the Coastal Plains and Piedmont sections of southern and southeastern United States. In favored locations they are found growing in great profusion, climbing to the tops of the tallest trees and trailing over the smaller trees and shrubs. When growing in the shade, especially in moist places, numerous aerial roots grow downward from the branches and if they reach to the ground often strike roots, thus becoming the means of the plants dividing into parts and propagating themselves.

The *Rotundifolia* have hard wood, and while the bark adheres very closely on the young branches, it sheds annually on the older wood and especially on the trunks of vigorous growing vines, but is never as shreddy as the bark of the *Euvtis* group. The trunks have a tendency to split into several parts as the vines grow old (fig. 1), though vines known to be a hundred years old often have solid treelike trunks. The wood varies in color from ashy gray to grayish brown, or sometimes yellowish brown, the young branches being covered with numerous small, prominent, warty lenticels. The

shoots are yellowish or reddish at the tip when young, are short jointed, angled, or sometimes flattened, and have intermittent, relatively long, tough, and strong, simple (unforked) tendrils of about the same color as the twig to which they belong. When permitted to



FIG. 1.—Trunk of an old *Rotundifolia* grapevine.

do so, the tendrils may foreshorten the young shoots, and sometimes when they encircle large branches need to be cut to prevent them from girdling and destroying them. The leaves are below medium size, more or less round to broadly cordate, with a wide, relatively

shallow basal sinus, generally not lobed, rarely slightly three-lobed, smooth and glabrous above and underneath, though there is sometimes a slight pubescence along the veins on the under side; margin serrate, with obtuse wide teeth. The color of the foliage varies from light to dark green, and the young foliage of the dark-fruited varieties often gives the vine a reddish tinge in the early part of the season. The fruit clusters are more or less roundish, ranging from loose to compact, and are relatively small, sometimes having 1 to 30 but generally 4 to 10 berries, the peduncle and pedicels are short, the berries are globular, sometimes slightly ovate or obovate, varying in color from green, pearly, or bronze to black, generally more or less covered with reddish or russet dots, the aroma is strong and peculiar to the group, the skin is usually thick and tough, although thin in some varieties, and the pulp varies with the varieties from meaty to melting and juicy. In most varieties the fruit ripens unevenly, the berries dropping more or less from the cluster when ripe. The seeds average two to four in number, are medium to very large, flattened, shallow, and broadly notched, with a very short pointed beak, and narrow raphe and chalaza surrounded by radiating wrinkles. The leafing, flowering, and fruiting periods are very late. In most cases the blossoms of the fruiting vines are practically self-sterile and subject to serious attacks of black-rot.

In the wild state *Vitis rotundifolia* has been known under such names as Bullace, Bullis, Muscadine, Fox, Mustang, and others less common. It is often referred to in the history of the discovery and settlement of the southeastern United States. It is native where it is now found wild. Adams and Barlowe, of Sir Walter Raleigh's colony which landed in Virginia in 1584, apparently referred to it when they stated:

On the 27th day of April in the year of our redemption 1584, we departed from England with two boats, well furnished with men and victuals, and found Roanoke Island on the 4th of July, and the smell was as sweet as if we had been in the midst of some delicate garden, and grapes grew abundantly—every shrub was covered, climbing toward the tops of the high cedars and we think the like is not to be found.

There are different species of grapes growing on Roanoke Island at present, but the *Rotundifolia* vines are greatly in excess of the others. There are no cedars anywhere near the supposed location of the Raleigh camp, but pines are numerous on the island and many of them are overgrown with *Rotundifolia*. The fruit even of wild *Rotundifolia* is esteemed and when ripe is gathered for culinary purposes from the vines known to bear the best fruit. The cultivated varieties are accidentally discovered natural seedlings of wild vines having superior qualities, and when their reputation became estab-

lished they were propagated and distributed, first to intimate friends and later in a commercial way.

VITIS MUNSONIANA.

Vitis munsoniana is similar to *Vitis rotundifolia* in some respects, but is different in others. It was first described by Rafinesque in 1830 as *Vitis pellata* or *Vitis floridiana*. In 1885 or 1886 specimens of the species were sent to Prof. T. V. Munson, of Denison, Tex., who described it as *V. floridiana*, but this designation was never generally accepted. Later, Simpson named the species *V. munsoniana*, the name now in common use. This species is a native of southern Florida, the Florida Keys, and the borders of the Gulf of Mexico. At its northern limits it overlaps into the territory of *V. rotundifolia*, and Hedrick speaks of it as a variation of *Rotundifolia* suited to subtropical conditions. The vines of *V. munsoniana* are slender, more trailing, and do not climb as high as *V. rotundifolia*. The leaves are generally smaller and the basal sinuses narrower, the marginal teeth generally less numerous, but more prominent, and the venation is also more prominent than with *V. rotundifolia*. The clusters of *V. munsoniana* contain more but smaller berries. The berries are quite persistent, usually of a shiny black color, covered with numerous reddish, brownish, or grayish dots, juicy, but with very little pulp and often of good flavor. (Pl. II, fig. 2.) There are three to four seeds, which are small and usually dark reddish brown in color. (Pl. II, fig. 1.) The vines leaf out, bloom, and fruit about the same time as *V. rotundifolia* in the same locality. All stages from fruit bud to ripe fruit may be found on the same vine late in the summer. No horticultural varieties of *V. munsoniana* have been produced, but the Department of Agriculture has now under test a number of *V. munsoniana* seedlings and hybrid seedlings of which *V. munsoniana* is one parent.

DISTRIBUTION OF MUSCADINE GRAPES.

Generally speaking the Muscadine grapes are at home in the Coastal Plains and lower Piedmont section of the southeastern and southern United States. There are several plants growing under cultivation in protected places in the vicinity of Washington, D. C. The natural northern limit is Virginia and Maryland. South of this these vines occur plentifully along the Atlantic coast to Florida, and then west along the Gulf coast to central Texas, thence northward along the Mississippi Valley to southeastern Missouri, *Vitis rotundifolia* covering almost this entire territory, but *V. munsoniana* being found only in Florida and on the borders of the Gulf of Mexico. The accompanying map (fig. 2) gives a better understanding of this distri-

bution. *V. rotundifolia* is found most abundantly in the tidewater sections and river valleys along the Atlantic coast, gradually disappearing as it approaches the Blue Ridge Mountains. The distribution of the cultivated varieties is very irregular, most of them being local. However, a few prominent varieties are cultivated throughout the entire Rotundifolia territory. Of the leading sorts the so-called Scuppernong or white varieties collectively are decidedly the most generally and extensively distributed. The other leading sorts in the order of their relative distribution are as follows: Flowers, James, Thomas, Mish, Memory, and Eden. The relatively small area in which each of these varieties is grown is due to the fact that they have not been

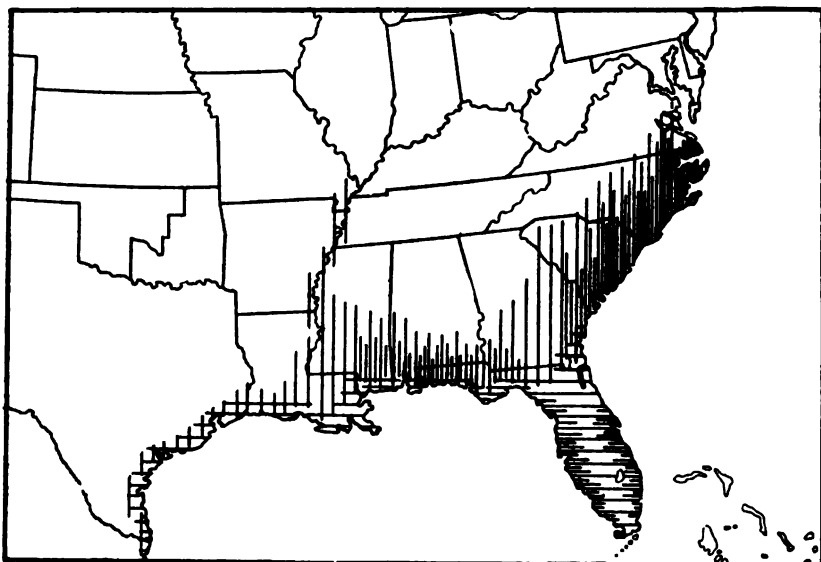


FIG. 2.—Sketch map of the southeastern portion of the United States, showing the natural distribution of Muscadine grapes. The vertical lines show the region where the Rotundifolia varieties grow and the horizontal lines the growing region of the Munsoniana varieties.

distributed throughout the Rotundifolia territory, and the investigation of the adaptability of these varieties to different conditions has not yet proceeded far enough to enable definite conclusions to be drawn. There is apparently no doubt that all the varieties mentioned can be successfully grown in other localities and to a much greater extent than at present. The accompanying map (fig. 3) shows the places at which the named varieties originated or are supposed to have originated.

It will be noted that nearly all originated in North Carolina and seven of them within a radius of 50 miles, including the towns of Marion, S. C., Whiteville, N. C., and Lumberton, N. C.

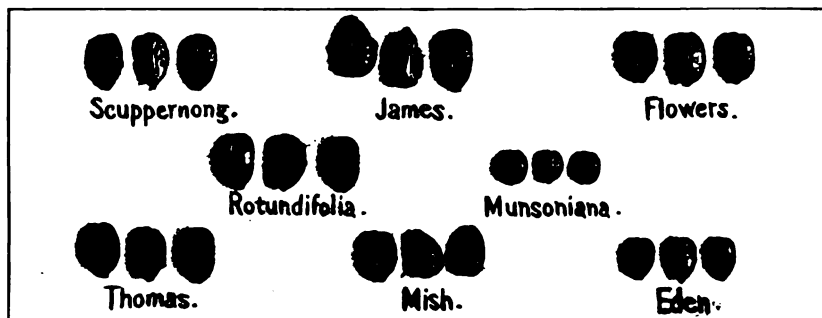


FIG 1.—TYPICAL ROTUNDIFOLIA AND MUNSONIANA SEEDS.



FIG. 2.—FRUIT AND BRANCHES OF VITIS MUNSONIANA.



FIG. 1.—A FRUITING ARM OF THE FLOWERS VINE SHOWN IN FIGURE 2, BELOW.

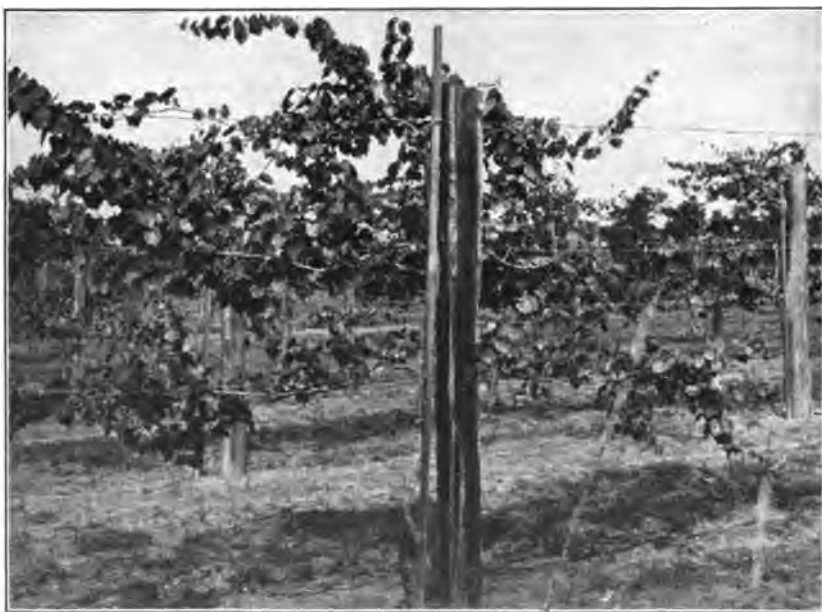


FIG. 2.—A VINE OF THE FLOWERS VARIETY TRAINED TO A 3-WIRE UPRIGHT TRELLIS IN THE COOPERATIVE EXPERIMENT VINEYARD, WILLARD, N. C.

FLORIDA.

Rotundifolia grapes have been grown for wine and domestic use in Florida since the early agricultural development of this country. Growing them for commercial purposes is generally incidental, for local markets, other fruits being thought more profitable in most sections of the State. Soon after the great freeze of the winter of 1894-95 a considerable number of vines of Rotundifolia and other grapes were planted in destroyed orange groves. The larger Rotundifolia vineyards did not generally prove profitable on account of the laws enacted restricting the sale of wines made from the grapes. Those near the larger towns yielded good returns on account of the local demand for the fruit. In fact, in the cities of Jacksonville, St. Augustine, New Smyrna, Sanford, Orlando, Maitland, Oviedo, Ocala, Gainesville, Waldo, Baldwin, Lake City, Tallahassee, De Funiak Springs, Milton, and Pensacola the Rotundifolia grape when ripe is the most important home-grown fruit in the markets, the

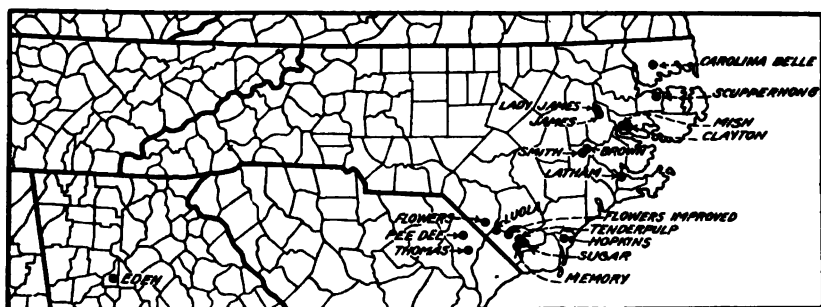


FIG. 3.—Sketch map of North Carolina and the adjacent territory, showing where the leading Rotundifolia varieties originated.

quantity of grapes incidentally seen on the market in these places when visited ranging from 1 or 2 to 20 or 30 bushels.

MORE than half the Rotundifolia grapes grown in Florida are of the light-colored varieties. The Flowers, Thomas, James, and Memory varieties seem to be next in order of importance after the Scuppernon. The Eden and Mish are also grown to a limited extent. In the northern part of the State wild Rotundifolia fruit is often sold in the markets. In the small towns and suburbs of the cities a great deal of the fruit is incidentally obtained from vines grown around homes, where besides yielding fruit they also serve as ornamentals, for in a subtropical climate they hold their foliage most of the year. The native grapes of Florida are largely Munsoniana and are found in great numbers in the hammock lands in the southern part of the State, along the rivers and along the Gulf in the northwestern part, through the southern central part of the State, and up through the

range of the citrus fruit. *Rotundifolia* grapes can, however, be successfully grown in these localities. Passing from the citrus district into the cotton belt, the wild *Munsoniana* vines gradually disappear and the *Rotundifolia* vines take their place. From Jacksonville to Pensacola the majority of the wild Muscadines are *Vitis rotundifolia*, but the fruit on them is hardly as large as on wild vines of the same species farther north. Although they can be grown to perfection there is less general interest manifested in the growing of Muscadine grapes in Florida than in Georgia and the Carolinas.

GULF AND SOUTH-CENTRAL STATES.

In the Gulf and South-Central States the soil formation and the climatic conditions are less favorable to the growing of the *Muscadinia* than along the coast in the South Atlantic States. *Rotundifolia* grapes are, however, quite generally grown in these States for both home use and local markets. Wild native vines grow plentifully and in great variety. The soils of Mississippi and the southern part of Alabama adapted to *Rotundifolia* compare favorably with those of Florida. The commercial vineyards formerly operated in these sections have in many cases deteriorated, owing to the fact that their crops, which were formerly made into wine, can not now be thus used on account of the local-option laws. Throughout Texas, northeastern Arkansas, southeastern Missouri, and northern Mississippi and Alabama *Rotundifolia* vines occur only occasionally and in limited numbers.

GEORGIA AND SOUTH CAROLINA.

In about three-fourths of Georgia and the coast section of South Carolina the conditions are well suited to *Rotundifolia* grapes, and they may be grown almost anywhere in these States with at least partial success. They are grown there principally for home consumption and local markets, although there are some commercial vineyards. The culture of *Rotundifolia* vines has gradually been extended as the population increased. The light-colored *Rotundifolia* varieties are mostly found on the markets. Next to these the Thomas is the most extensively grown. This variety originated in Marion County, S. C., and in the immediate vicinity of its origin the Thomas outnumbers all other varieties planted.

NORTH CAROLINA.

The *Rotundifolia* grape industry has reached its greatest development in North Carolina, owing principally to the fact that the people of that State have always been interested in grape growing, and the wine manufacturers have devoted a great deal of their time and

means to encouraging the industry. The early inhabitants of the State also gave some attention to selecting and placing under cultivation the best varieties of native grapes, and it was thus that the Scuppernong, James, Mish, Flowers, Memory, and several other varieties which will be described later on were introduced. The natural distribution of *Vitis rotundifolia* in North Carolina has already been referred to. Generally speaking, this species is found native only in the eastern half and in greatest abundance only in the eastern third of the State. It can, however, be grown in all but the extreme western part.

The earliest vineyards in the State were of the white type and consisted as a rule of small plantings devoted to the growing of grapes for home use and local trade. It became known early in the development of the industry in North Carolina that the white varieties produced a good sweet wine, and many grapes were made into wine for home and local consumption. The first commercial vineyard, known as the Medoc vineyard (Pl. I), located 12 miles southwest of Enfield, N. C., was started by Dr. Sidney Weller in 1835. The grapes from it have always been made into wine and its acreage has been increased from time to time until it now consists of 150 acres of the white varieties, 35 acres of the James, 25 acres of the Mish, 5 acres of the Beula, and about 5 acres of miscellaneous vines, making a total of about 210 acres. In 1847 the Tokay vineyard near Fayetteville was started by Col. W. J. Green. (Pl. V, fig. 2.) It originally consisted of 85 acres of white grapes. Since then vines of the James, Mish, and Flowers varieties have been added, bringing the total up to about 100 acres. The grapes from the Medoc and Tokay vineyards are all made into wine.

In North Carolina grape growing was recommended immediately after the Civil War to help solve existing labor problems and to replace cotton raising, which for many was then unprofitable. This resulted in many plantings, mostly small vineyards, ranging from one-fourth of an acre to 2 acres. Most of the leading varieties of Muscadine grapes were introduced at that time, each variety being extensively planted in the vicinity in which it originated. This condition continues to the present time, the leading varieties being grown more extensively than any others in the localities where they were found. It is not a case of better adaptability, but rather a case of lack of general distribution that has so far limited the wider planting of these varieties. In North Carolina this epoch of vineyard planting was followed by a period of vineyard neglect. At present, matters seem to be adjusting themselves again, and commercial vineyards are being planted, mostly in the eastern part of the State.

PROPAGATION OF MUSCADINE GRAPES.

Like grapes of other species the *Muscadinia* may be propagated from seeds, layers, cuttings, and grafts. They should be grown from seed only when new varieties are desired, the seedlings being usually too variable for other purposes, as many of them will be sterile or unfruitful and many of the fruiting vines will resemble the wild parents. Of 570 typical *Rotundifolia* seedlings grown by the Department of Agriculture and planted in the *Rotundifolia* experiment vineyard at Willard, N. C., 66.3 per cent have proved sterile or staminate and most of the fertile or pistillate vines have been worthless. It also appears that the majority of fruiting seedlings from light-colored *Rotundifolia* produce dark-colored fruit. Van Buren states that from 1860 to 1870 he raised 3,000 seedlings from the seeds of white grapes in an effort to produce white *Rotundifolia*, and found only one white one among them. He also says that three-fourths of all the plants proved staminate. Mr. M. T. Williams has a vineyard 7 miles southwest of Rocky Mount, N. C., which he raised from seed of white *Rotundifolia*. He says of it:

Years ago I planted seeds of white *Rotundifolia*, expecting to get a vineyard of white grapes. Instead, I got a hundred or more varieties of grapes, only two of which were white, and these two, like all but one of the others, were inferior to the parent.

It is possible, however, to produce white seedlings or varieties. If the staminate vines are studied carefully and pollen from those having yellowish young shoots or growing tips is selected for crossing on the white-fruited varieties which also have yellowish growing tips (dark varieties having reddish growing tips) a large proportion of and sometimes all the resulting seedlings will have yellowish growing shoots, and of these the fruiting vines will bear white fruit. This is shown conclusively by some of the experiments made by the Department of Agriculture. From crosses of a Scuppernong vine with pollen from two white staminate vines, 91 seedlings resulted, 82, or 90.1 per cent, of which produced white fruit, while 85 seedlings resulting from crosses of the same Scuppernong vine with two dark staminates having reddish growing tips produced 85, or 100 per cent, dark vines.

SEEDS.

As soon as the fruit is ripe the seeds should be separated from the pulp and stored in sand very slightly moist, not wet, and should be protected from heat, drying out, and vermin. A well-drained, fertile, light soil, which must be well prepared, should be selected for the nursery. As early in the spring as possible the seeds should be sown 1 inch apart in rows 2 feet apart and covered to a depth of

about 1 inch. When the seedlings first appear it is a good idea to shade them with brush or a lattice. As soon as they are large enough, either a stake reaching 2 feet above the ground or its equivalent should be given each plant for support. The plants may be left in the nursery until the following spring, but it is best to take up the vines in the late fall, when they should be culled and the inferior ones discarded. The good plants should be thoroughly heeled in in well-drained soil. In the spring they can be planted out for testing. Rows 8 feet apart and the vines 4 feet apart in the rows is a convenient spacing for testing. As they begin to fruit most of them will prove worthless and can be removed.

CUTTINGS. .

In that portion of the *Rotundifolia* territory where sufficient cold weather prevails to insure a real dormant condition, cuttings are best prepared as soon as possible after the vines have become dormant, provided proper care is given to the cuttings. In the more tropical parts of Florida good results are reported with *Rotundifolia* cuttings made and the vines pruned shortly after the crop has been harvested. The cuttings should be from 10 to 12 inches long, made from the last season's growth, and medium-sized, short-jointed wood is preferred. The cuttings should be made with a slanting cut, close below the lower bud, and about three-quarters of an inch of wood should be left above the upper eye. It will be found advantageous to leave on the cutting a small piece of the old wood or a whorl of buds where the shoot starts from the old wood. The cuttings should be tied in bundles of convenient size, with the butts all the same way. (Fig. 4.)

The cuttings can be planted in the nursery soon after they have been made; in fact, it is claimed by some that it is best to plant them at once. If the cuttings are to be held over winter for spring planting, the bundles should be heeled in or buried in the ground, with the top ends down and the butts covered well with 3 to 6 inches of soil. Inversion causes a callus to form at the butts, while the tops remain dormant, the cuttings being then ready to form rootlets as soon as they are planted. If heeled in with the tops up, growth often starts before sufficient roots have formed to support it. When the ground has become warm enough in the spring, plant them in soil made friable and mellow by plowing and cultivating. This can



FIG. 4.—A bundle of grape cuttings.

be done by throwing out slanting trenches 2 or 3 feet apart with a plow and deepening them with a spade if necessary. The cuttings should be planted 2 to 3 inches apart, firming the ground well around their bases, being sure to set them so deep that when covered only the upper buds will project slightly. If fine soil is thrown over them they will be all the better for having this mulch. They should be kept clear of weeds and the ground frequently stirred to keep it moist and mellow, because *Rotundifolia* cuttings are usually difficult to root.

LAYERS.

Layering is the most common method practiced by grape growers and commercial nurserymen in propagating *Rotundifolia* vines. Canes may be layered at any season of the year. They are most frequently layered in midsummer, when canes of the same season's growth are used. These are bent down to the ground and covered with soil, the laterals being allowed to project above the ground. To induce the formation of roots a slight incision is sometimes made in the node, opposite the lateral. Roots will have formed by fall, and the layered canes may then be cut from the parent vine and divided, the laterals which were left usually forming the new plants. These plants should be thoroughly heeled in and held until spring. In general practice, however, the layers are not disturbed until needed in the spring, when they are taken up and planted at once.

Where vines have been trained on overhead arbors it is often impossible to get the canes down to the ground without taking down part of the arbor. In such cases the canes may be layered in boxes of soil placed upon the arbor. Where many plants are wanted, large branches may be buried, allowing the laterals to project above the ground. Commercial nurserymen grow plants especially for layering and never allow them to grow high above the ground. Each season, usually in August, the young growth made during the season is covered with soil, and during the winter all the plants produced are cut from the mother vine. This leaves nothing of the original vines except the trunks and spurs, which produce many new vigorous shoots and which in due time may again be layered.

The method of layering *Euvtis* vines can also be followed with *Rotundifolia*. This method differs from that just described in that canes of the previous year's growth starting above ground are layered. The nearer the base of the vines these canes start, the more convenient they will be for the purpose. During the previous summer, shoots starting on the vine close to the ground should be left for layering and these canes forced to grow as long as possible. In pruning the layer canes, all the well-developed buds should be left.

A shallow trench, say 2 inches deep and as long as the cane, is made and the cane fastened down into it. Each bud on the cane will usually produce a shoot, which should be made to grow upward in the open trench. When the shoots have well started, a slight incision on the node opposite should be made to induce the formation of roots, after which the trench can be filled with soil. The plants are taken up in the fall or spring, being divided by cutting the original cane between the shoots, each of which will have its own system of roots, the shoot becoming the stem of the vine. Layering by this method may be done in either the fall or the spring.

GRAFTING.

Grafting is entirely practicable, but seldom resorted to with *Rotundifolia*, and for this reason will not be described here.¹ Grafting may serve several useful purposes in a *Rotundifolia* vineyard. Worthless seedlings may be converted into standard varieties by means of grafting. A spur in the top of each pistillate vine can be grafted with a staminate scion while the vines are young enough to be bent down, thus enabling the vineyard to be planted entirely with pistillate vines instead of partly with staminate vines to serve as pollinizers. Another useful application of grafting is to promote the rooting of *Rotundifolia* cuttings simply by grafting roughly a piece of vine root into the butt end of the cutting. This operation is easily learned and quickly performed, and can be done indoors when weather conditions prevent outdoor work.

SOILS.

Of the land adapted to the growing of *Rotundifolia* grapes, the greater portion of the virgin soil is occupied with species of pines, while on that under cultivation cotton is grown. While the vines will grow on any soil suitable for cotton, ideal pine or cotton lands should not be selected for the best results. Soils adapted to growing Sea Island cotton are better. The best soils for *Rotundifolia* grapes are the well-drained, siliceous soils found bordering the coast and river banks throughout the Atlantic tidewater section. Different species of oaks, especially the live oak, and other hardwoods, in addition to occasional pines and other soft-wooded trees, abound in these soils in the virgin state. In parts of the coast region these lands are known as sandy ridges, in other sections as hammock and trucking soils, and sometimes as light, sandy lands. The ideal soil

¹ Those desiring information will find the methods of grafting generally practiced with grapes fully described in Farmers' Bulletin 471, entitled "Grape Propagation, Pruning, and Training," which may be had free on application to a Member of Congress or to the Secretary of Agriculture.

must contain a sufficient amount of moisture and plant food and must be something more than an ordinary light, sandy soil. It should be open and well drained but not necessarily very deep, provided the subsoil is not too heavy, for the Muscadine grapes have a shallow, spreading root system.

PREPARATION OF THE LAND.

If the Muscadine vineyard is to be planted on new ground, the growing of some cultivated crop the year previous is recommended. Since tobacco does well on new land it is a good crop for this purpose where it will succeed; otherwise corn, cotton, or any annual crop requiring cultivation, and wherever possible, a catch crop of some leguminous plant, such as cowpeas, should be grown and turned under to add humus to the soil. The three things most needed on southern farms are more humus in the soil, better drainage, and more efficient labor. When the vines are to be planted the soil should be thoroughly and deeply plowed, pulverized, and put in as good condition as possible. Muscadine grapes do not grow readily at the start and no pains should be spared either in the preparation of the soil or in planting the vines, in order to secure a good stand. It is useless to plant these varieties in wet soil.

T P T P T
P T P T P
T P T P T
P T P T P

FIG. 5.—Diagram showing the method employed in alternating permanent and temporary plantings of grapevines: T, Temporary; P, permanent.

PLANTING.

The distance apart that *Rotundifolia* vines should be planted depends on the variety and whether they are to be trained to overhead arbors, trellises, or some other system. The James and Flowers varieties can be successfully grown closer together than the Scuppernong, Thomas, or Eden. For an upright trellis the vines should be planted half as far apart each way as when trained on arbors.

A comparison of these two methods of training will be discussed later in this bulletin. If the vines are to be trained on overhead arbors, they are generally planted about 20 feet apart each way. If upright trellises are to be used, judging from the results of the experiments of the Department of Agriculture and from other available information, 10 feet apart each way is thought advisable. Should this prove too close as the vines approach full size, alternate vines in each row may be removed. In this case half the vines will be only temporary and should be removed as indicated in the accompanying diagram (fig. 5), in which the letter "T" indicates temporary vines and "P" permanent vines. In this manner at least one-half of a crop and two full crops can be obtained from the temporary vines before

the permanent vines will need the full space. This would certainly more than pay for the expense of growing the temporary vines.

Bulletin 132 of the South Carolina Agricultural Experiment Station recommends that *Rotundifolia* for training on upright trellises be planted in rows 15 feet apart and the vines 30 feet apart in the rows. So far, the observation of the writers and the results of experiments indicate that these distances are too great. However, this is still an open question and until further experimental demonstrations can be made vineyardists will have to depend on their own judgment. When planted 10 by 10 feet, 435 vines will be required to plant an acre, and when 20 by 20 feet, 108 vines will be necessary for the same area. The methods of laying out and staking the land for planting



FIG. 6.—*Rotundifolia* grapevines as received for planting.

have been described in so many publications that they need not be repeated here.

Planting can be done either in the spring or in the fall. It is generally done in the spring, about the time the buds burst and growth starts. When taking the plants from the nursery or where they have been heeled in, it is a good plan to place them in a wheelbarrow or cart with moist dirt or sand about the roots or to cover them with wet burlap in order to prevent their drying out. It is an advantage for more than one person to do the work of planting. Before planting, all diseased or broken roots should be cut off and the roots shortened if necessary. On young plants the top should be shortened to the required length, and where the plants are more than 1 year old the top should be cut back to one short spur. (Figs. 6 and 7.) The hole should be dug wide enough to prevent crowding the roots

and so deep that when the vine is planted only the top bud will be slightly above the ground. This will usually require a hole about 15 inches deep and 12 inches wide. After the hole has been dug, a little of the good, loose surface soil should be thrown into the bottom and the vine placed in position. Then more surface soil should be thrown in and worked well between the roots of the plant. The ground should be especially well firmed around the roots and the whole mass of soil firmed as the hole is filled. When planted only the top bud of the vine should be slightly above ground. Great care should be taken in planting in order to secure good results. Three things should be particularly observed:

(1) Care should be taken to keep the roots of the plants from drying out;

(2) The roots and tops of plants should be pruned properly before planting; and

(3) The soil should be carefully firmed around the roots.

Devices are sometimes used in planting to show the exact position of the vine. This should not be necessary if the land has been cor-



FIG. 7.—*Rotundifolia* grapevines pruned ready for planting.

rectly laid out and staked and care taken to place each vine in proper position in the hole.

CULTIVATION.

The proper methods of cultivating *Rotundifolia* vineyards are disputed points. Some claim that because the vines have a shallow, spreading root system (fig. 8) cultivation will disturb and reduce the roots and seriously affect the vitality of the plants. Others claim that the roots are much benefited by cultivation. This question is being given very careful study in the work of the Department of Agriculture. Observation shows that almost without exception the best yields are obtained from cultivated vineyards and that the best and most successful growers are cultivating their vines. By cultivation is meant a shallow stirring of the surface soil and not deep plowing. In locations where the water table is close to the surface or where there is a stratum of hardpan clay directly under the top soil, the roots also are nearest the surface. In deeper and better aerated

soils the roots strike deeper. Where cultivation is practiced from the beginning, *Rotundifolia* roots will not grow so close to the surface. A dust mulch on the surface appears not to injure the roots and benefits the plant. This hypothesis has been followed in the *Rotundifolia* experiment vineyard of the Department of Agriculture, at Willard, N. C., and the results have thus far been satisfactory. The best information obtainable to date suggests the following course in regard to cultivation and cover crops:

- (1) Care should be taken to drain the land.
- (2) In the spring, before planting, the land should be well and

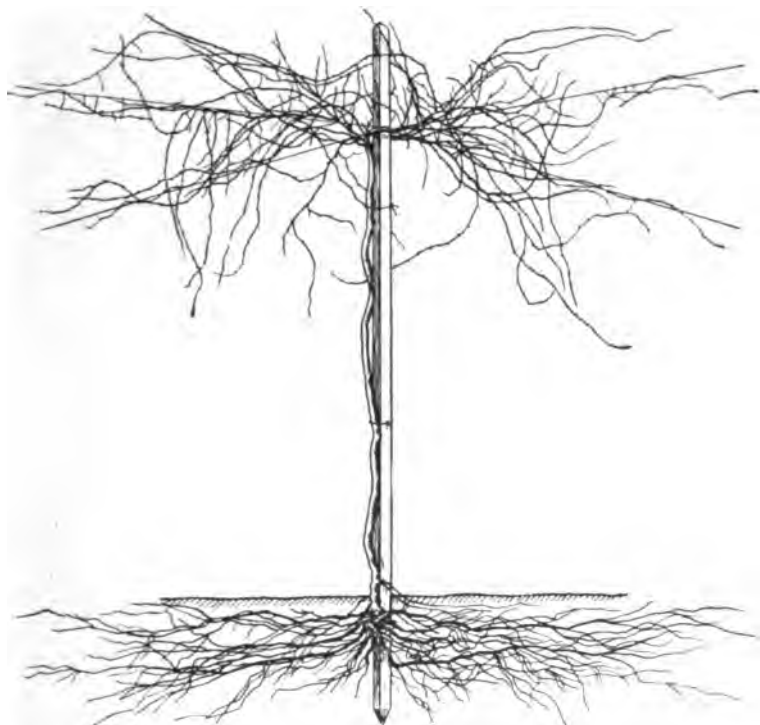


FIG. 8.—*Rotundifolia* grapevine, showing shallow, spreading root system.

deeply plowed. Following in the surface plow furrows with a sub-soiler will prove most advantageous.

(3) The year the vines are planted, truck crops, strawberries, cotton, tobacco, or similar crops can be grown, truck crops being much preferred. Peanuts are also an ideal cover crop, since they require cultivation, add humus and nitrogen to the soil, and produce a paying crop.

At least 3 feet should be left vacant on each side of the vine rows, the vines being treated as a hoed crop. If truck crops, such as potatoes, early cabbage, beans, or peas, are planted, it is also possible

to follow with a crop of cowpeas planted late in the summer to be turned under the following spring.

The vineyard may be again intercropped during the second year. If, however, the vines are trained to upright trellises and the rows are only 10 feet apart, only two rows of truck or other crops can be planted. A leguminous catch crop may again be planted.

After the second year the vines should be allowed full possession of the land and the soil should be given frequent, shallow, clean culture throughout the first part of the season and a leguminous catch crop planted in the latter part of the season for turning under. Grain crops, especially oats, should never be planted in a properly located Muscadine vineyard.

In the cooperative experiment vineyard at Willard, N. C., bur clover is proving a great success both as a cover and as a green-manure crop. When planted in the early fall of the first year, bur clover will produce a winter cover crop and ripen its seeds the following May. The dead tops can then be raked away from the spiral seed pods which have ripened and fallen to the ground. The seeds may then be brushed into piles and bagged. During the past season (1911) the North Carolina State Department of Agriculture harvested over 100 bushels of seed (in the bur) from about 1 acre of the experiment vineyard. The surplus seed was sold to a large vineyard company for \$1.50 a bushel. In this way a vineyard on upright trellises may be made to yield a very profitable annual catch crop. After the bur clover seed is harvested, the ground should be thoroughly cultivated in order to turn under the remaining bur clover pods for reseeding. From about July 1 to July 10, three rows of cowpeas may be planted between the vine rows if the latter are 10 feet apart, and when the cowpeas die in the fall the bur clover will be ready to take possession of the land.

The few small roots cut by cultivation will not injure the vines; they will rather be induced to yield more fruit. If the surface soil is shallow it will probably be best to use cutaway or disk harrows in cultivating. The Muscadine vines, being naturally shallow feeders, should be induced to send down their roots as much as possible, which can be done by stirring the surface regularly. Cultivation should be level at all times.

The foregoing observations made in the cooperative experiment vineyard and in existing commercial vineyards are presented as suggestions only and are not to be considered as final conclusions.

FERTILIZATION.

Very little definite information is available relative to the best fertilizers for *Rotundifolia* grapes, which respond readily to proper fertilizer treatment. Nearly all soils suitable for these vines lack

humus; therefore, where good stable manure is available, applications of not to exceed 6 tons to the acre will prove useful. Where manure is scarce, the bulk of the necessary organic matter may be supplied by growing and turning under leguminous crops, but commercial fertilizers will be needed in most cases in addition to these green-manure crops. For this purpose a general fertilizer containing nitrogen, phosphorus, and potassium, in which most soils are found deficient, will be best. The kind and quantity of fertilizer needed will depend largely on the character of the soil. Sandy soils usually require heavier fertilization than sandy loams, which in turn need more than red clays. Commercial fertilizers are not as



FIG. 9.—Vines trained by the multiple cross-wire or overhead system.

important as the growing and turning under of cover or green-manure crops, but both are needed to obtain the best results.

PRUNING AND TRAINING.

The system of training followed in the growing of *Rotundifolia* vines for commercial purposes has been and still is almost exclusively on overhead arbors. (Fig. 9.)

When planted in sufficient number to be called a vineyard the vines are usually set 10 by 20, 15 by 15, or 20 by 20 feet apart.

In following the overhead system of training, a durable post reaching 7 feet above the ground is planted at each vine. Rows of well-braced posts at the ends of the rows on all four sides are set at

the boundaries of the vineyard. From the tops of these posts a No. 10 galvanized wire is run along the tops of the inside posts in each row in both directions as a governor wire. No. 14 wires, 2 feet apart, are run parallel with the governor wires until in this manner the entire area has been regularly covered, in a rectangular criss-cross manner. Some growers construct the arbors entirely of wood, using slats instead of wires for this purpose. (Pl. VI, fig. 1.)

In training the vines to the overhead-arbor system a single trunk should be caused to grow from the ground alongside the post, to which it should be tied, and after it has reached the top it should be



FIG. 10.—A grapevine 37 years old, severely pruned.

pinched in or cut back in order to force it to throw out shoots, which are allowed to grow and spread over the arbor. After this the prevailing practice is to do no more pruning, under the supposition that the vines naturally prune themselves and that radical pruning or cutting back will kill them.

In order to determine the correctness or incorrectness of the growers' theories regarding pruning, a number of experiments were started in 1908 and have been continued for three seasons in commercial *Rotundifolia* vineyards in North Carolina and Florida. The investigations were designed to cover all phases of pruning from the

mildest to the severest treatments, such as simple foreshortening of the branches, mild thinning out of the branches, regular renewal, cutting back entire tops and growing new ones, removing all diseased parts from badly diseased vines, restoring the vines to vigor, etc.

Figure 10 shows a large 37-year-old vine just pruned that was badly diseased, from which all diseased parts have been removed and the entire top severely thinned out and cut back. The vine has since become healthy, vigorous, and productive.

The pruning experiments of the Department of Agriculture show conclusively that not only will *Rotundifolia* vines stand pruning, but

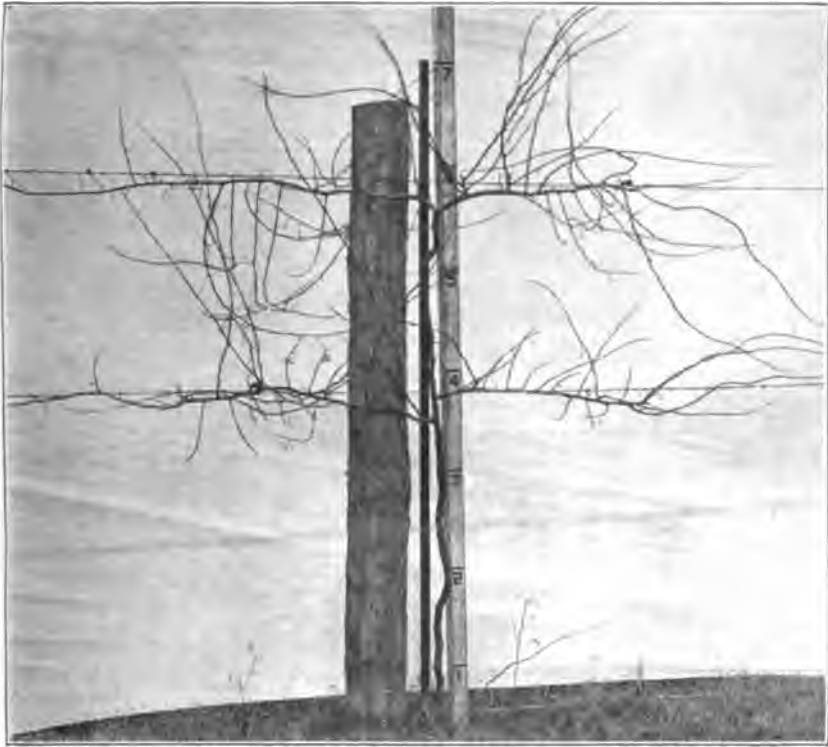


FIG. 11.—Unpruned grapevine trained by the 4-arm renewal system.

in order to have permanently healthy vines they must be systematically and regularly pruned. Early observations and study showed that the training systems, if systems they may be called, practiced by commercial growers were crude and wasteful at best, yielding only partial returns. Therefore, a series of plantings consisting of regular checks of the leading commercial varieties was made in 1907 in the cooperative experiment vineyard at Willard, N. C., for the purpose of making varietal studies, as well as to investigate the

effects of a number of different pruning and training systems with a view of determining those most suitable for *Rotundifolia* vines. In addition to the overhead cross-wire system (fig. 9) such upright systems as the fan and the 2-arm, 4-arm, 6-arm, etc., renewal systems are included in the work. Figures 11 and 12 show a vine, before and after pruning, respectively, trained to the 4-arm renewal system, and

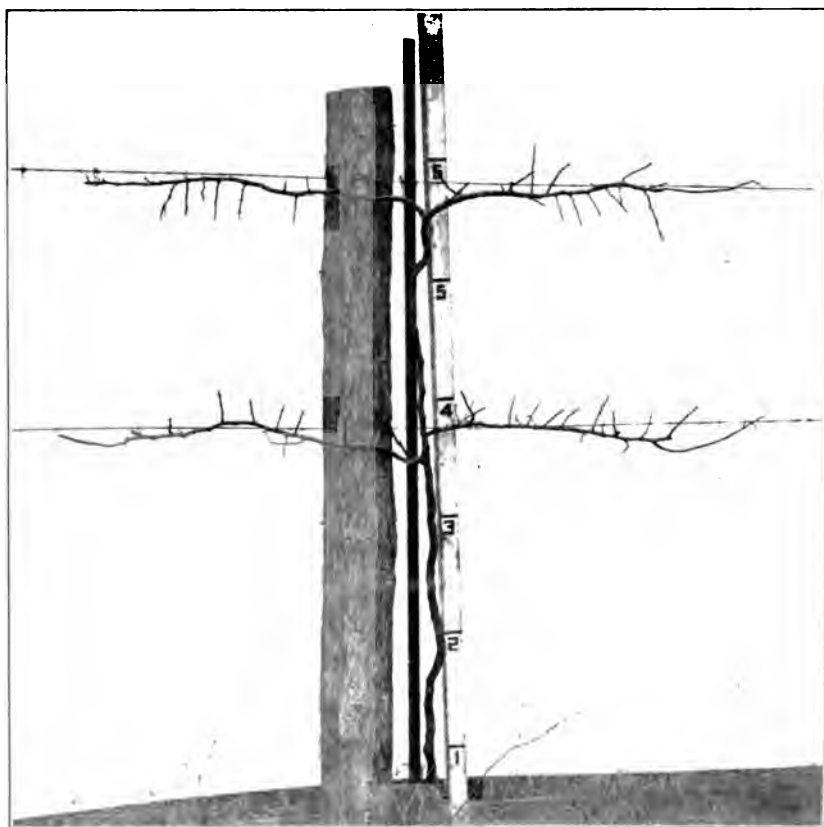


FIG. 12.—Pruned grapevine trained by the 4-arm renewal system.

figures 13 and 14 one also before and after pruning, trained to the 6-arm renewal system.

Plate III, figures 1 and 2, shows a Flowers vine trained to the 6-arm renewal system and a portion of one of the arms with fruit on it. The pruning and training experiments have so far yielded results beyond expectations, and lead to the belief that vines trained by the upright systems not only bear paying crops at least a year earlier than those trained by the overhead system, but also bear larger crops of much better fruit which ripens more evenly. In addition, the vines occupy only about one-half the space required by the



FIG. 1.—ROTUNDIFOLIA GRAPES IN CARRIERS FOR SHIPMENT.



FIG. 2.—ROTUNDIFOLIA GRAPES IN BASKETS FOR SHIPMENT.



FIG. 3.—ROTUNDIFOLIA GRAPES IN BERRY BOXES FOR SHIPMENT.



FIG. 4.—JARRED GRAPES IN BARRELS AND FAN BLOWER FOR CLEANING THEM.



FIG. 1.—GENERAL VIEW OF SOUTHERN PINES VINEYARD, SOUTHERN PINES, N. C.



FIG. 2.—GENERAL VIEW OF TOKAY VINEYARD, FAYETTEVILLE, N. C.



FIG. 3.—REMAINS OF THE STOVER VINEYARD, COLUMBIA, S. C.



FIG. 4.—AN OLD WINE PRESS ON THE CANNON FARM, CHAPEL HILL, N. C.

overhead-arbor system, the fruit can be harvested more cheaply and to better advantage, and insect enemies and diseases of the vine and fruit can be more easily controlled on them.

HARVESTING AND HANDLING.

Rotundifolia vines have been almost entirely grown on overhead arbors in the past, the fruit being made into wine, and under such conditions the general practice of jarring the grapes from the vines

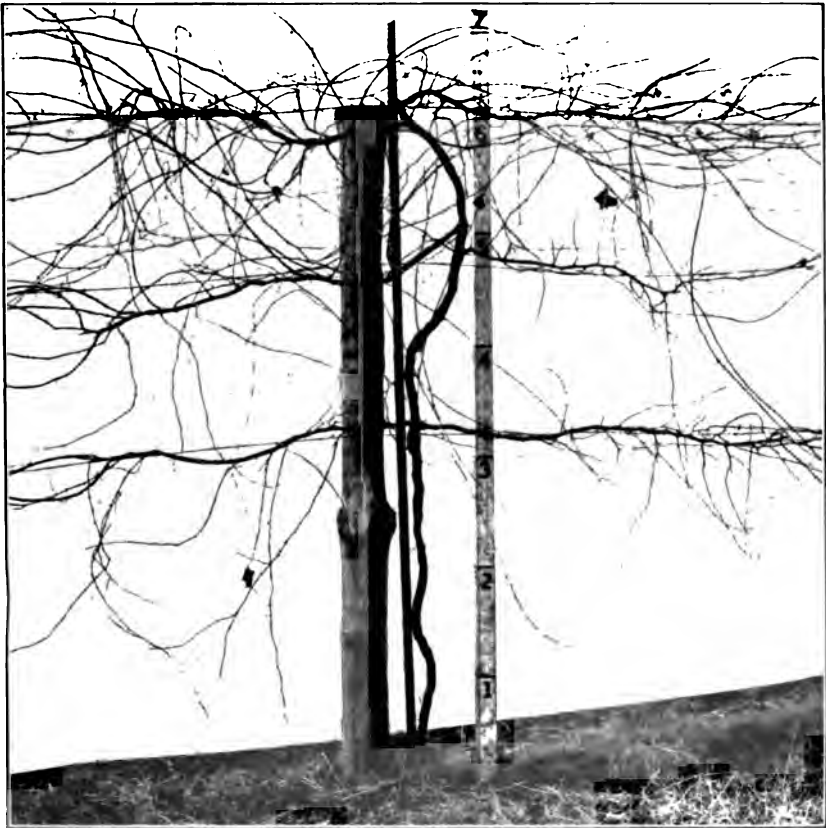


FIG. 13.—Unpruned grapevine trained by the 6-arm renewal system.

is perhaps the most practical method of harvesting. If the vines are trained to upright trellises or if the fruit is intended for shipping or table use the grapes should be picked by hand in order to be sound and clean. On account of the presence of leaves, twigs, etc., mixed with the grapes jarred from the vines, wine and grape-juice manufacturers will pay 5 to 15 cents a bushel more for hand-picked grapes. The growers who make a practice of hand picking claim that the work can be done at practically no greater expense than is necessary to

shake off and clean a crop, and the increased price obtained for the fruit will more than pay the difference.

A description of the harvesting of *Rotundifolia* grapes by the jarring method will be interesting to those not familiar with it. (Pl. I.) Poles are attached to sheets of canvas measuring 6 by 12 feet and having leather handles. A man is placed at each end of these sheets and four men with two sheets work together. The wide sides of the two sheets are brought close together under each vine, with the trunk

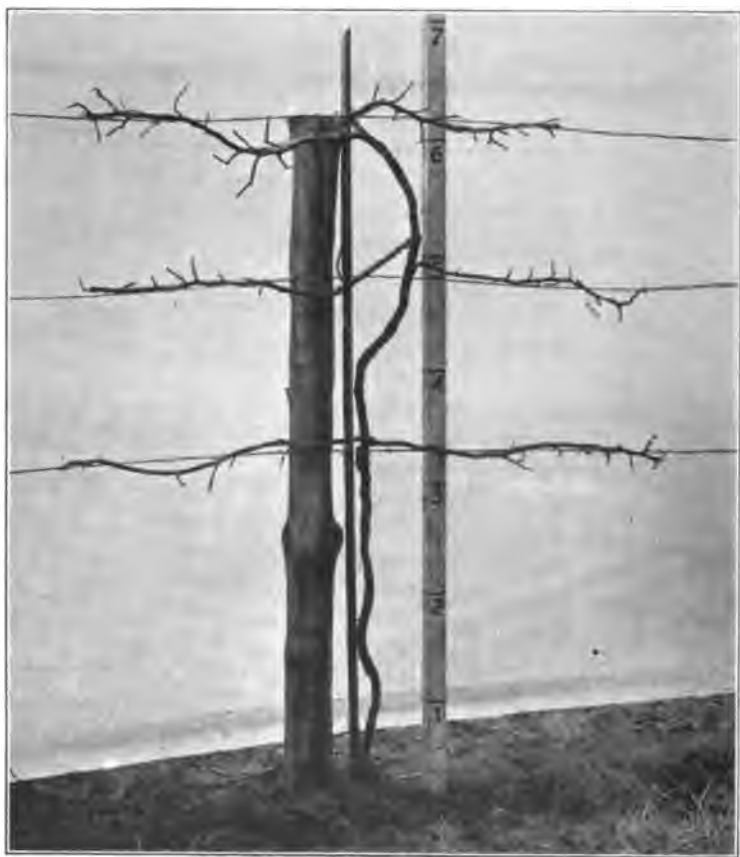


FIG. 14.—Pruned grapevine trained by the 6-arm renewal system.

of the vine in the middle. The vines are then jarred, the berries falling into the sheets. Those not caught by the sheets or that have fallen to the ground by the shaking of the trellis when the fruit of the adjoining vines was harvested, etc., and which are usually of the best quality, are picked up by hand. The writers are informed that it costs approximately 15 cents a bushel to harvest the fruit on the ground and 12 cents to harvest that which falls on the sheets.

The fruit is put in boxes or barrels, and if the quantity is not large the leaves, sticks, etc., which become mixed with the fruit are removed by hand. If there is a considerable quantity of fruit some mechanical means, such as ordinary grain fan mills, are used to clean it. (Pl. IV, fig. 4.) After cleaning, the fruit is hauled or shipped to the winery. In wineries with modern equipment there are blowers which thoroughly clean the fruit. These are located near the end of the elevators that carry the fruit to the crusher.

A common and very objectionable practice followed in harvesting *Rotundifolia* grapes, especially by the jarring method, is that of gathering the fruit all at once, whereas there should be at least three periods of harvesting. When harvested at one time the best quality of fruit ripens, falls to the ground, and is lost before the harvest has commenced and the last part of the crop is thrashed from the vines in a half-ripe condition along with the ripe fruit. In this manner not only is the first and best fruit entirely lost, but the harvested fruit is inferior in quality, which necessarily results in a poor product from the entire yield.

YIELDS AND RETURNS.

Great variations occur in the yields from *Rotundifolia* vines. At times there are record-breaking yields and, again, small yields are reported, the small yields resulting from black-rot, coulure, wet weather, self-sterility, lack of cultivation, fertilization, etc., lack of pruning, age of vines, and various other causes. In spite of this, *Rotundifolia* vines are said to be among the safest and most prolific of fruit-bearing plants. (Pl. III, fig. 2.) While in one of the largest *Rotundifolia* vineyards there has been only a partial crop during the last three years, owing to various causes, another grower reports a yield of 177 bushels of grapes from 4-year-old James vines, in addition to a bale of cotton to the acre. A Florida grower estimated his crop of white *Rotundifolia* and Thomas grapes for the season of 1911 at 280 bushels to the acre. An average yield of 27 bushels an acre from 4-year-old vines, 100 bushels from 5-year-old vines, and 150 bushels to the acre when the vines are in full bearing should be obtained.

The prices paid for *Rotundifolia* grapes depend on the season, the quality of fruit, and the market. In years when the crop is short better prices are usually paid than when there is a heavy crop. Aside from the grapes sold and shipped to wineries, grapes as a rule sell for more in the cities and larger towns than in smaller places, the local demand being somewhat in proportion to the population. In such localities fruit of good quality will bring a much better price than inferior fruit. Hand-picked fruit in half-bushel peach baskets or in berry boxes usually brings from \$1 to \$2 per bushel. Grapes har-

vested by jarring are usually sent to the wineries and bring an average of 75 cents per bushel of 60 pounds. The highest price paid for this quality of fruit was reached in 1910, when \$2.25 per bushel (f. o. b. shipping point) was paid for white *Rotundifolia*.

In many localities certain growers have built up quite a reputation for themselves on choice, hand-picked fruit, which they ship to special customers in distant markets. (Pl. IV, figs. 1, 2, and 3.) For this purpose the James variety is usually grown because the berries adhere well and are of good size and flavor. Several growers ship as far north as New York and Boston, getting from \$2 to \$2.50 gross per bushel crate. In shipping, three styles of carriers are used—the 24-box strawberry crate, the 6-basket peach crate, and the 8-pound grape basket. More attention should be given to this phase of the industry. The varieties best suited for shipping are the James, Memory, Flowers, and Mish.

In the fall of 1910 shipments of the James, Thomas, and Eden varieties were sent from the *Rotundifolia* experiment vineyard at Willard, N. C., to Washington, D. C., part of the consignment being in strawberry boxes and the remainder in bushel baskets. No important difference could be noted in the two lots on their arrival at Washington. The James variety arrived in perfect condition in both packages; of the Eden 30 per cent and of the Thomas 35 per cent had shelled. More extensive experiments along this line are contemplated.

RELATION OF WINE MAKING TO THE ROTUNDIFOLIA-GRAPE INDUSTRY.

The growth of the *Rotundifolia*-grape industry is at present dependent on the wine industry of the section where the fruit is produced. In fact, the bulk of the grapes now produced is used for wine making. Wine from *Rotundifolia* grapes has been made in an amateur way along the South Atlantic coast region for many years and probably ever since the country was first settled. Large vineyards have been successfully operated for a number of years, but with the exception of the Medoc vineyard, in which the first plantings were made in 1835, and the Tokay vineyard, started in 1847, the early vineyards have been allowed to deteriorate or have been destroyed in recent years. The old Cannon vineyard, at Chapel Hill, N. C. (Pl. V, fig. 4), and the Stover vineyard at Columbia, S. C. (Pl. V, fig. 3) are remains of such vineyards. Each of these originally consisted of about 50 acres and was operated as early as 1850 or 1860. The Stover vineyard has been allowed to go down entirely while only about 30 small arbors of the Cannon vineyard are left. The Stover place was operated by Col. Stover, a German, and his wines are said to have been

very popular in the local markets. The remains of another old vineyard, now owned by Daniel Pratt, are reported to exist at Prattville, 14 miles northwest of Montgomery, Ala. The Petigrew vineyards, on Lake Scuppernong, in North Carolina, planted by Rev. Charles Petigrew in 1774, were operated prior to 1850. The *Rotundifolia* wineries of note at present are located at Norfolk, Va., and Wilmington, N. C. These plants have modern equipment. The growers appear to be dependent on these establishments, or at least will be in the near future, to handle their grapes, and there seems to be no doubt that these firms will be able to use all the grapes offered them for some years to come.

TABLE I.—*Brix readings and acid tests of Muscadine grapes.*

Location of vineyard.	Variety.	Date (1910).	Brix readings corrected to 17.5° C.	Acid as tartaric (grams per 100 c. c.) in —		Condition.
				Free-run juice.	Juice after grinding.	
Cooperative experiment vineyard, Willard, N. C.	James.....	Sept. 1	11.9	0.397	0.75	Not fully ripe.
Do.....	Eden.....	do.....	11.78	.99	1.07	Do.
Do.....	Thomas.....	do.....	15.2	.43	.58	Do.
Do.....	Scuppernong.....	do.....	14.12	.61	.79	Do.
Ronnoc grove, New Smyrna, Fla.	Memory.....	Sept. 8	15.36	.465	.66	Good.
Hinkle vineyard, Maitland, Fla.	Thomas.....	Sept. 10	19.02	.09	.34	Overripe.
Do.....	Scuppernong.....	do.....	16.0	.54	.72	Do.
L. O. Booher, Ocala, Fla.	Munsoniana.....	Sept. 11	14.5	1.31	1.31	Good.
A. W. Curry, Winfield, Fla.	Scuppernong.....	Sept. 13	16.18	.25	.41	Do.
J. J. Powers, Welton, Fla.	Flowers.....	do.....	15.28	.53	.62	Do.
M. Foley, Aberdeen, N. C.	Seedling.....	Sept. 21	16.16	.697	.787	Do.
Do.....	James.....	do.....	14.06	.33	.585	Do.
Southern Pines Vineyard Co., Southern Pines, N. C.	Scuppernong.....	do.....	17.06	.607	.817	Do.
Tokay vineyard, Fayetteville, N. C.	Mish.....	Sept. 22	12.55	.26	.39	Do.
Do.....	Flowers.....	do.....	13.56	.607	.68	Do.
J. S. Breece, Fayetteville, N. C.	James.....	do.....	15.13	.24	.435	Do.
M. T. Williams, Rocky Mount, N. C.	Mish.....	Sept. 29	19.04	.51	.63	Do.
Do.....	James (large).....	do.....	14.02	.735	.967	Do.
R. R. Bulluck, Enfield, N. C.	James.....	Oct. 1	13.77	.....	.....	Do.
Medoc vineyard, Enfield, N. C.	Beula.....	do.....	13.67	.....	.....	Do.
Do.....	Mish.....	do.....	13.67	.....	.....	Do.
Do.....	James.....	do.....	18.17	.....	.....	Do.
G. W. Lennon, Whiteville, N. C.	Lennon.....	Oct. 6	13.93	.278	.397	Do.
Do.....	George.....	do.....	15.56	.375	.337	Do.
J. L. Memory, Whiteville, N. C.	Thomas.....	do.....	15.36	.375	.54	Do.
H. W. Whitehurst, Newbern, N. C.	Mish.....	do.....	17.16	.39	.465	Do.
Do.....	Scuppernong.....	do.....	16.06	.48	.72	Do.
Do.....	James.....	do.....	13.15	.177	.39	Do.
J. Ivy Brown, Kinston, N. C.	Brown.....	Oct. 9	14.02	.607	.727	Do.
Ellen Griffin, Washington, N. C.	Clayton.....	do.....	14.12	.54	.68	Do.
Mrs. J. H. Willis, Washington, N. C.	Mish.....	do.....	16.93	.307	.435	Do.
Charles James, Grindool, N. C.	Lady James.....	Oct. 10	14.87	.38	.495	Do.

The wine made from *Rotundifolia* grapes is very distinct in flavor and other characteristics, and on that account a special trade for it must be developed. Those accustomed to the flavor are very partial

to this wine. The skins of all *Rotundifolia* grapes are very high in acid, have a pronounced acrid flavor, and contain almost the entire coloring values of the dark varieties. Tables I and II, giving Brix readings and acid content of the Muscadine varieties, will indicate quite closely the juice and wine values of the commercial *Rotundifolia* varieties now under culture.

The Brix readings were corrected to 17.5° C. Acid was determined by titrating 10 c. c. portions of the juice with tenth-normal alkali, using litmus solution on a spot plate as an indicator, and expressed as grams per 100 c. c. of acid as tartaric. The Brix spindle readings indicate with considerable accuracy the sugar contents. These and the acid determinations are of unheated juice of freshly pressed, also freshly ground fruit, which in each instance was first strained through muslin.

UNFERMENTED GRAPE JUICE.

A very palatable unfermented juice for home use can be made from *Rotundifolia* grapes, though the experiments thus far made show that much better results must be accomplished before such juices can compete with those made for commercial purposes from the *Euvitis* varieties. The unfermented *Rotundifolia* juices, although quite pleasant when fresh or as they run from the crusher, not only seem devoid of fruity flavor after pasteurizing, but in the juice of some varieties a foreign, insipid, somewhat disagreeable flavor develops. The juice kept from fermenting by holding in cold storage also appears devoid of fruity flavor. When made and kept, either by cold storage or pasteurization, the addition of sugar brings out the fruity flavor. It is more than likely that by evaporation a very palatable sirup could also be made from *Rotundifolia* grapes.

Farmers' Bulletin 175, entitled "Home Manufacture and Use of Unfermented Grape Juice," which can be had free on application to a Member of Congress or to the Secretary of Agriculture, explains fully how to make and keep unfermented grape juice.

OTHER USES OF MUSCADINE GRAPES.

As a fruit to be consumed fresh, *Rotundifolia* grapes are much relished, especially if eaten at the time they are picked from the vine. The flavor deteriorates quite rapidly after picking.

As a result of the very crude growing and pruning methods at present practiced by the growers, the berries of the clusters of some varieties ripen unevenly and the individual berries shell from the stem as they ripen. This not only detracts from their use as a shipping fruit, but the juice exuding from the skins of the berries makes them sticky and unsightly and they soon ferment and spoil. The

large seeds are also objectionable, although this is of minor importance. The very thick, tough skin of some varieties also disqualifies them for the table and lessens their value for other purposes.

All the *Rotundifolia* varieties make most excellent jellies and preserves. For making preserves, the pulp should be separated from the skins, the seeds extracted, and after the skins have been cooked tender the pulp should be put with them again and the making of the preserves completed.

The fresh hulls when dried will keep almost indefinitely. These and the canned grapes are said to make fine pies. A delightful catchup is made from the fresh grapes.

There are a number of other purposes for which these grapes are used, but it is impossible to mention or describe these within the limits of this bulletin.

There are very marked differences in the varieties relative to the color, size, and flavor of the fruit, the thickness and toughness of the skin, the size of the seed, the texture and size of the pulp, their juiciness, and their sugar and acid content, so that by selecting and improving the varieties for special purposes and adjusting them to soil conditions, as well as by giving them better methods of culture and training, no doubt their value for various purposes can be much enhanced.

BRIX READINGS AND ACID CONTENT OF MUSCADINE GRAPES.

During the fall of 1910 investigations were started to ascertain the average Brix readings and acid content of the different Muscadine varieties produced under like conditions, as well as in the same varieties when grown in different localities and environment. Tables II and III present the results obtained during one season only. On account of unavoidable delays in carrying out the field work of the season many varieties had ripened in certain places before the analyses were made and could not be tested. The results obtained give a fair idea of the average Brix reading and acid content of the different varieties tested. Each figure in Table II is an average of three determinations. With a few exceptions, as noted in Table I, only fully ripe grapes were used. Separate determinations were made of the acid content of the free-run juice and of the total juice that could be obtained after grinding the grapes in an ordinary meat grinder. There is practically no difference in the Brix readings of the free-run and the total juice.

TABLE II.—Average Brix readings and acid content of varieties of *Rotundifolia* grapes from all tests.

Variety or species.	Number of tests.	Average Brix readings of juices (corrected to 17.5°C.)	Average acid (grams per 100 c. c.) in —	
			Free-run juice.	Juice after grinding.
James.....	7	13.877	0.375	0.625
Thomas.....	3	16.58	.298	.486
Scuppernong.....	5	15.88	.498	.691
Flowers.....	2	14.42	.568	.65
Mish.....	5	16.77	.466	.48
Eden.....	1	11.78	.99	1.07
Memory.....	1	15.36	.465	.65
Munsoniana.....	1	14.5	1.31	1.31
Seedling from Foley.....	1	16.16	.697	.787
Beula.....	1	13.67		
Lennon.....	1	13.93	.276	.397
George.....	1	15.56	.27	.337
Brown.....	1	14.02	.607	.727
Clayton Improved.....	1	14.12	.54	.68
Lady James.....	1	14.87	.38	.495

TABLE III.—Comparison of the seven leading varieties of *Muscadine* grapes in accordance with their rank in Brix readings and acid content.

Rank.	Brix readings.	Acid in free-run juice.	Acid in total juice after grinding.
1	Mish.....	Eden.....	Eden.
2	Thomas.....	Flowers.....	Scuppernong.
3	Scuppernong.....	Scuppernong.....	Memory.
4	Memory.....	Mish.....	Flowers.
5	Flowers.....	Memory.....	James.
6	James.....	James.....	Thomas.
7	Eden.....	Thomas.....	Mish.

INSECTS AND DISEASES.

One of the chief advantages of the Muscadine grapes is their relative freedom from disease and insect injury. So far no insect injury has been noticed, other than an occasional slight damage from one of the flea beetles (*Haltica chalybea*, Ill.). Black-rot (*Guignardia bidwellii*) is known to have done serious injury in several of the larger vineyards, and the more progressive growers are resorting to spraying in order to combat this disease. Black-rot attacks both the leaves and the bloom clusters. Its attacks on the leaves produce brick-red spots in which many tiny black dots are found. These dots are the fruiting bodies of the fungus and each produces many spores, which are capable of causing additional disease. The fungus kills the leaves or reduces their food-elaborating surface, which causes a weakening of the vine and consequent reduction of the crop in the following years.

The black-rot attacks the bloom clusters as they are about to open, killing the individual buds and thereby reducing the size of the crop.

After the fruit has once set it appears to be rarely attacked by black-rot and in this particular Muscadine grapes differ from other species of which both the green and ripening berries are attacked. It is beyond the province of this bulletin to enter into a full discussion of the black-rot fungus, as this involves a special pathological investigation. Persons interested should consult the publications of the Department of Agriculture dealing with grape diseases.¹

RESEARCHES IN SELF-FERTILITY, STERILITY, AND BREEDING.

Breeding and pollinating experiments are being conducted with a view of producing more desirable varieties and also as a means of studying the relative fertility of pollen and the receptiveness of the pistils of both the *Rotundifolia* and *Munsoniana* varieties. While these investigations are far from complete, sufficient progress has been made to warrant a few statements at this time.

The breeding experiments have in view improvement along the following general lines: (1) Better adherence of berry to cluster, (2) increased size of cluster, (3) higher sugar content, (4) decreased acid content, (5) pulp improvement, (6) decreased size of seed, (7) thinner skin, (8) more uniform ripening, and (9) self-fertility.

These are high ideals which if accomplished at all will most likely require years of research. The fact that the present commercial varieties are apparently self-sterile increases the complexity of the problem. The sterility study was started in 1907 to meet a demand for information along this line. The Muscadine vines were known to be of two types as regards the character of their bloom. Over 60 per cent of *Muscadinia* seedlings produce staminate, or male, blooms, the remainder producing flowers having both stamens and pistils in which the female organs are capable of producing normal fruit if fertilized. The stamens of this type of flower are, however, short and recurved. The question raised, therefore, was whether the pollen from stamens of this type of flower can fertilize the pistils of the same flower or whether it is necessary to obtain pollen from wild staminate vines.

The experiments in testing the self-fertility of varieties were started in 1907 at eight different places in Florida, South Carolina, and North Carolina by covering the blossoms of 11 varieties with bags to exclude foreign pollen. Microscopical tests of *Muscadinia* pollen were begun, similar to those made of *Euvitis* varieties by Mr. N. O.

¹ Quaintance, A. L., and Shear, C. L. Insect and fungous enemies of the grape east of the Rocky Mountains. Farmers' Bulletin 284, U. S. Dept. of Agriculture. 1907.

Shear, C. L., Miles, G. F., and Hawkins, L. A. The control of black-rot of the grape. Bulletin 155, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

Booth, of the New York State Agricultural Experiment Station at Geneva, N. Y.¹ A limited number of germination tests of pollen in 20 per cent (standard) sugar solution were also made, while 775 pollinating operations for breeding purposes yielded additional information. Careful field studies have been made from the beginning in Florida, Georgia, South Carolina, North Carolina, and Virginia on the influence of male vines and other environmental factors on the size of the crop, of the structure of the flowers of cultivated and wild vines, and of the proportion of flowers setting fruit. In 1911 the pollinating experiments were confined to New Smyrna, Ocala (Pl. VI., fig. 1), and Maitland, Fla., and Willard and Wilmington, N. C. During the season 106 *Rotundifolia* and *Munsoniana* vines of 14 varieties were used and 2,431 clusters, representing about 68,300 blooms, were operated on, and simultaneous microscopic tests and pollen germination tests in sugar solution were made as checks on the field work. The work is, of course, not yet completed. The following are, however, some results and conclusions reached:

(1) *Vitis munsoniana* varieties naturally set a higher percentage of fruit than those of *V. rotundifolia*.

(2) Weather conditions greatly influence the setting of fruit, dry, sunny weather at blooming time favoring it, while cool, showery weather hinders it by washing off the pollen, preventing the work of insects and promoting the spread of black-rot.

(3) Artificial hand cross-pollination in bags with pollen from male vines materially increases the setting of fruit, and through the daily hand-pollinating of unbagged blossoms the setting of fruit may be still further increased. In 1911 very accurate estimates made of the natural setting of fruit in North Carolina and Florida showed this to be 10.6 per cent of the total blooms, or 14.41 per cent below the maximum, resulting from the combined natural and artificial pollination under the most favorable circumstances.

(4) All tests so far made show that the Scuppernong, James, Thomas, Flowers, Mish, Eden, Memory, and Hopkins varieties are practically incapable of fertilizing themselves or each other.

(5) Muscadine vines with perfect flowers can be produced. Two vines of this character, grown by the writers from seed, are now fruiting in the cooperative experiment vineyard at Willard, N. C. One of these is a white *Rotundifolia* seedling, the other a dark-fruited cross between the Eden variety and a staminate vine. Their dried pollen resembles that of staminate *Rotundifolia* and germinates in sugar solution. They set fruit under natural conditions, and other varieties have been successfully fertilized with

¹ N. O. Booth. Investigations concerning the self-fertility of the grape, 1900-1902. Bulletin 224, New York Agricultural Experiment Station, 1902, p. 291-302.



FIG. 1.—TYPICAL ROTUNDIFOLIA GRAPE ARBOR. THE BAGS ON THE VINE INCLOSE CLUSTERS USED IN POLLINATING EXPERIMENTS.



FIG. 2.—SEEDLINGS IN BREEDING BLOCK IN THE COOPERATIVE EXPERIMENT VINEYARD, WILLARD, N. C.

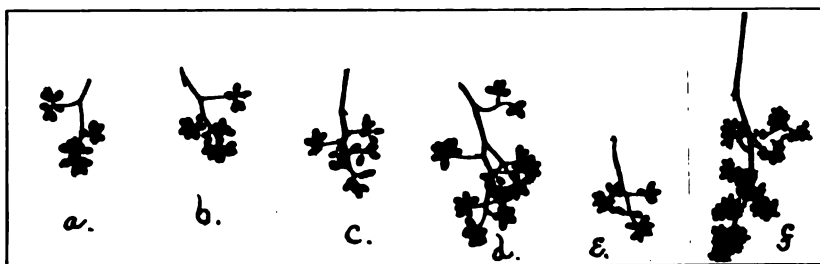


FIG. 1.—TYPICAL ROTUNDIFOLIA CLUSTERS BEFORE BLOOMING: *a*, JAMES; *b*, THOMAS; *c*, FLOWERS; *d*, EDEN; *e*, SCUPPERNON; *f*, STAMINATE.

(One-half size.)

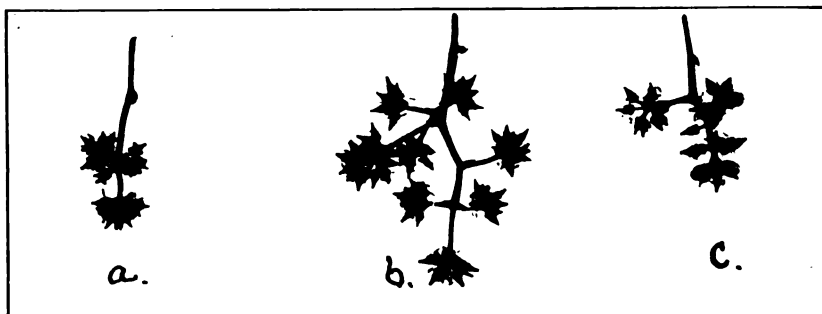


FIG. 2.—TYPICAL PISTILLATE ROTUNDIFOLIA CLUSTERS IN BLOOM: *a*, JAMES; *b*, EDEN; *c*, THOMAS.

(Natural size.)



FIG. 3.—THREE STAMINATE ROTUNDIFOLIA CLUSTERS IN BLOOM: *a*, AN AVERAGE CLUSTER; *b* AND *c*, TYPES OF CLUSTERS FROM TWO VERY FINE STAMINATE VINES IN THE BREEDING PLAT AT WILLARD, N. C.

(Natural size.)

each of them. A flower cluster of the white seedling was bagged and produced 25 per cent of fruit, which is a very high percentage. One wild *Rotundifolia* vine with perfect flowers but not self-fertile was reported by Reimer.¹

(6) In artificial pollination the increased percentage of fruit setting on the commercial varieties is not in proportion to their natural setting. This is because in some varieties all buds on individual clusters become receptive at the same time, while with others the individual pistils become receptive at different times.

(7) The congeniality of fertile pollen varies with different varieties. Thus, a particular staminate vine might be a good pollinizer for a Scuppernong vine but not for an Eden, or vice versa.

(8) Fertile pollen of some *Vinifera* varieties is not congenial to the leading *Rotundifolia* varieties.

(9) The average number of blooms and berries per cluster under natural conditions, based on accurate estimates, is shown in Table IV.

TABLE IV.—Average number of blooms and berries to the cluster of varieties of *Muscadine* grapes.

Variety or species.	Average number of blooms to the cluster.	Average number of berries to the cluster.	Variety or species.	Average number of blooms to the cluster.	Average number of berries to the cluster.
Munsoniana.....	34.5	.....	Eden.....	48.5	12.9
James.....	25.3	6.5	Scuppernong.....	20.1	2
Thomas.....	31.1	5.3	Memory.....	14.6	5.5
Flowers.....	33.5	7.4	Hopkins.....	16.2	.....

(10) Insects, especially a small beelike fly and a small long-horned beetle (*Copidita thoracica*), are most active agents in carrying pollen from one vine to another.

(11) Where other conditions are the same, fruiting vines growing near male vines set more fruit than those at a greater distance.

(12) There is great variation among male vines relative to size of bloom cluster, date of blooming, length of blooming period, and profuseness of bloom. In planting male vines as pollinizers care should be taken to select only those that bloom at the same time as the fruiting vines they are intended to pollinate.

(13) In large Muscadine vineyards provision should be made to protect the wild male vines growing in near-by woods and fence corners either by planting them in or around the vineyard or by grafting male scions into the tops of a number of the fruiting vines.

VARIETIES.

From time to time reports have been received from persons claiming that vines sold to them were not true to name. The Department of Agriculture has also had a similar experience. While some of this

¹ Bulletin 209, North Carolina Agricultural Experiment Station.

disappointment has undoubtedly been caused by carelessness on the part of nurserymen, much of it is due to a lack of knowledge regarding the identity of the different varieties.

With a view to eliminating the existing confusion regarding the varieties of *Rotundifolia*, as complete descriptions as possible of all of the more promising varieties are given in the following paragraphs, the varieties being arranged in accordance with their relative value.

Scuppernong.

The name "Scuppernong" as used has more than one meaning. Some apply the word to the entire *Rotundifolia* species, while others apply it to the cultivated varieties of *Rotundifolia* in contradistinction to the word "Bullace," which they apply to the wild Muscadines. Still others call the white-fruited *Rotundifolia* the white Scuppernong, and the black-fruited *Rotundifolia* the black Scuppernong. Again, a great many designate all the light-colored *Rotundifolia* now under cultivation as Scuppernong. Such a confusion of uses for the same name—and this will become still greater unless stopped—demands either that some understanding be reached relative to its use or that it be discontinued.

The name "Scuppernong" has been in general use too long to be discarded, and a specific definition for it should be adopted. All who have studied the situation, including the horticulturists of the various States of the southeastern United States, will undoubtedly agree that the name should be applied only to a single, white-fruited *Rotundifolia* which is supposed to have originated in the northeastern part of North Carolina and to which the name was first applied.

This variety is, however, not as clearly defined as it should be, owing to the fact that its origin and early history have not been absolutely determined. The writers have found many so-called Scuppernong vines under cultivation which are not alike and have located wild white-fruited *Rotundifolia*, two of them being young vines, in the States of Alabama, Florida, North Carolina, and South Carolina, and widely separated parts of the *Rotundifolia* territory, and they are further convinced that all nurseries and venders are not selling the same variety as Scuppernong. There seem to be at least three strains of light-colored *Rotundifolia* among the cultivated varieties of Scuppernong grapes of to-day. The most extensively planted strain has medium-sized clusters and berries. Upon ripening, the fruit of this strain turns a reddish brown and the berries adhere well for *Rotundifolia*, the fruit even tending to shrivel a little without falling from the stem. It ripens about the middle of September and is thought to be the real Scuppernong, because it was found most abundant in that part of North Carolina where this variety is supposed to have originated. This is the strain referred to in this bulletin wherever the Scuppernong is mentioned as a variety. Another strain ripens about the same time, but has a pearly instead of a bronze color, a thinner skin, smaller seeds, less adherence, and less sugar. A third strain ripens in October after the two just mentioned are gone, has far better adherence to the stem, better bunching qualities, a smaller berry, and higher acidity. These strains have been seen growing side by side, so the differences noted in them are therefore not due to difference in environment.

The Scuppernong is at present the preeminent grape in the Southeast and is the chief representative of the *Rotundifolia* species. Bulletin 201 of the North Carolina Agricultural Experiment Station deals extensively with the origin and history of the Scuppernong, and independent and simultaneous investigations by the United States Department of Agriculture have also brought out the same facts and conclusions.

The name is of native Indian origin, but the exact origin of the variety is not known. It is supposed to have originated in Tyrrell County, in northeastern North Carolina.

In this section the name Scuppernong has been given to a swamp, a lake (now called Phelps Lake), a river, and a town. The Scuppernong grape is said to have been found on Roanoke Island at the time of the landing of Sir Walter Raleigh's colony, and there is a tradition that an old vine now growing on this island is the original. This, however, has been quite fully disproved, though the vine is very old. Mr. D. Calvin Jones, an agriculturist of note in North Carolina during the early part of the nine-



FIG. 15.—Lower side of a Scuppernong leaf. (Natural size.)

teenth century and agricultural editor of the Raleigh (N. C.) Star, gives the following history of the naming of the Scuppernong grape:¹

This grape and vine had the name Scuppernong given to them by Henderson and myself in compliment of James Blount, of Scuppernong, N. C., who first diffused a general knowledge of it in several well-written communications in our paper, and it is cultivated with more success on that river than in any other part of the State, perhaps, except on the island of Roanoke.

From the time of its discovery the Scuppernong has steadily increased in popularity. It has been distributed to all parts of the Rotundifolia territory and today is more extensively grown than any other variety.

¹ The American Farmer, vol. 3, 1822, p. 332.

The description of *Vitis rotundifolia* given at the beginning of this bulletin would, in general, suit the Scuppernong. The vine is a vigorous, rank grower, with long, slender, yellowish brown, smooth canes, covered with many very small, light-brown dots or lenticels. The pith is greenish and the tendrils single and intermittent. The growing tips are yellowish or greenish, foliage medium dense, leaves medium size, cordate, with an average width of $2\frac{1}{2}$ inches and a length of 3 inches, margin mediumly serrate, and texture thin in comparison with other *Rotundifolia* varieties. (Figs. 15 and 16.) The flowers have reflex stamens and open about May 27 in North



FIG. 16.—Upper side of a Scuppernong leaf. (Natural size.)

Carolina. The cluster (Pl. VII, fig. 2) is round, small to medium size, moderately compact, having 1 to 15, but generally 2 to 6 berries to the cluster. The berries are large, averaging three-fourths of an inch in diameter, round, and, when fully ripe, bronze or reddish brown in color, ripening the middle of August in Florida and the middle of September in North Carolina. The berries often ripen unevenly and when fully ripe fall readily from the clusters. The skin is medium thick, tough, covered with numerous small but prominent russet dots and sometimes russet blotches, but contains no pigment. The flesh is generally pale green, very juicy, tender, soft, fine grained,

musky, sweet and sprightly, and of good quality. The flavor is distinctly "scuppernong," sweet, sprightly, and agreeable when the berries are fresh, but deteriorating rapidly after picking. The seeds are large, typical of *Rotundifolia*, adhering slightly to the pulp. This variety is suited for home use and wine making, and thrives best on well-drained, sandy-loam soils. bears abundantly, though not as much as some of the dark varieties, and is also more susceptible to black-rot. This is the only *Rotundifolia* variety at present in demand by large wineries.

Flowers.

The Flowers variety is the oldest black *Rotundifolia* in cultivation. It was discovered in 1819 growing in Flowers Swamp, 15 miles south of Lumberton, Robeson



FIG. 17.—Upper side of a Flowers leaf. (Natural size.)

Co., N. C., on the road from Lumberton to Fair Bluff, by "Popping Billy" Flowers, and transplanted by him to a place a few hundred yards away. It has since been grown quite extensively for home use in the section where it was found, and is considered second only to the Thomas, which was discovered about 25 miles farther south. The spot on which the Flowers was found is a sandy loam considerably elevated above the surrounding lands and it thrives best in similar locations. The vine

has an upright, slender growth, more open than and hardly as vigorous and robust as other *Rotundifolia* varieties.

The leaves (figs. 17 and 18) vary in size but average $2\frac{1}{2}$ inches in width and $3\frac{1}{2}$ inches in length and are thick, rather dark green, slick, leathery, cordate, with sharp-pointed tip and a margin sharply serrate.

The cluster is large for *Rotundifolia*, almost round, of medium compactness, containing generally from 6 to 10 medium-sized purplish black berries slightly oval in shape. (Pl. III, figs. 1 and 2.) The skin is very thick and tough and only faintly



FIG. 18.—Lower side of a Flowers leaf. (Natural size.)

marked with dots. The flesh is white, meaty, tough, and not very juicy, containing three to four seeds, parting with difficulty from the pulp and more angular and square than the other varieties. The flavor is sweetish, lacks sprightliness, and is of medium quality.

The distinguishing characteristics of the Flowers variety are a strong tendency to bunch, a strong adherence to the peduncle, good shipping qualities, late ripening, coarseness and meateness of flesh, and thickness of skin, differing in all these respects from any of the other varieties with the exception of the Luola, which ripens at the same time.



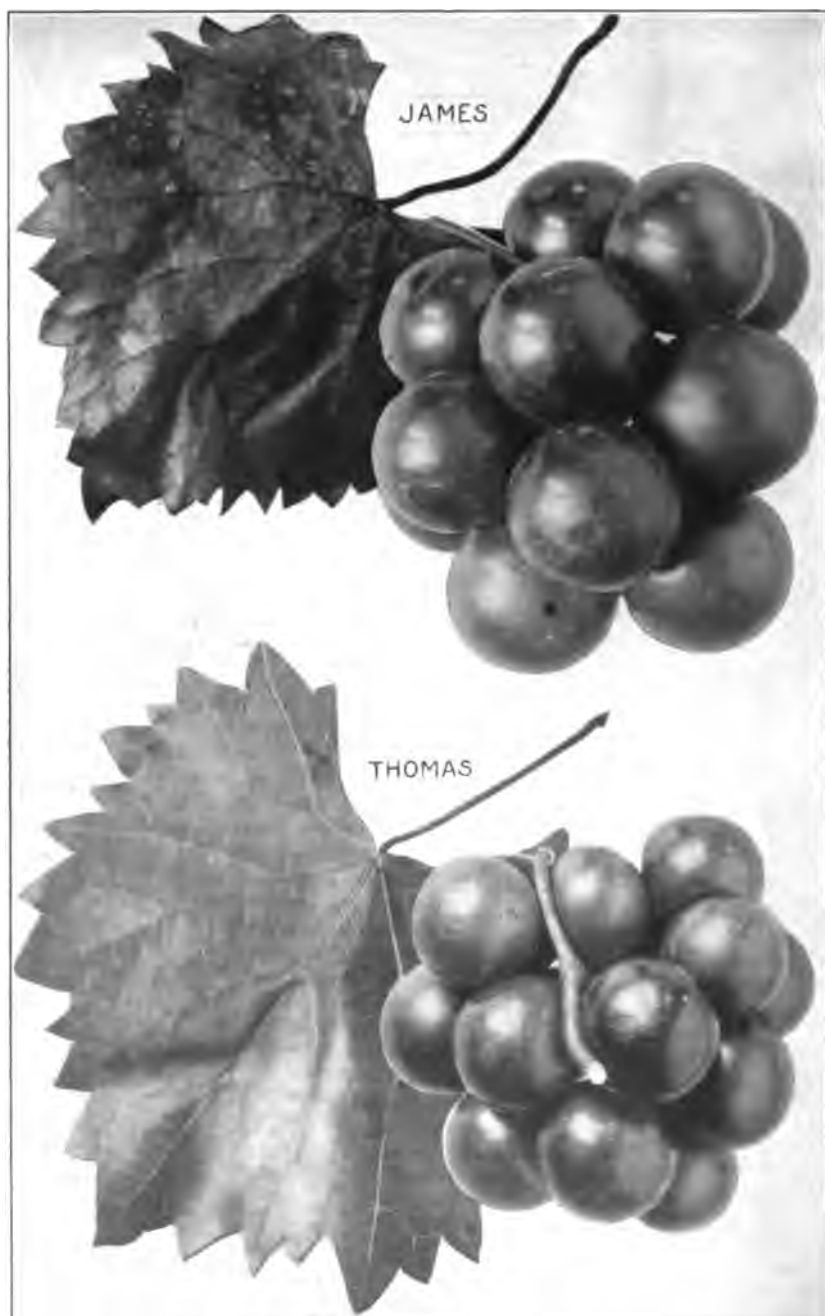
FIG. 1.—VIEW OF SWANS POINT, WHERE THE MISH GRAPE WAS DISCOVERED.



FIG. 2.—ORIGINAL SITE OF THE THOMAS VINE, MARION, S. C.



FIG. 3.—ORIGINAL JAMES VINE WITH THE OWNER, MR. B. M. W. JAMES, SEATED BENEATH, GRINDOOL, N. C.



CLUSTER AND LEAF OF THE JAMES GRAPE AND OF THE THOMAS GRAPE.
(Natural size.)

The Flowers variety is principally used for wine, although the wine made from it is not as good as that made from either the Scuppernong, Mish, James, Thomas, or Memory variety. It appears to be well adapted to the soils of both North Carolina and South Carolina. It is found to thrive in northern Florida and is said to do well as far south as the Florida Keys. The berries adhere to the bunch better than those of any other *Rotundifolia* variety now in cultivation, the fibro-vascular bundles from the peduncle extending into the berry before breaking, instead of breaking at the peduncle, which makes it a good shipper. It is also one of the best, if not the best bearer. In the *Rotundifolia* experiment vineyard at Willard, N. C., at 3 years of age, the Flowers and the Eden yielded 57 bushels an acre, as compared with 36 bushels an acre from the James and Thomas varieties.

James.

The James was discovered by Mr. B. W. M. James, of Grindool, N. C., about 1866 or 1867, growing not far from Grindool Creek, a few hundred yards from Grindool post office, now called Whitehurst, located in Pitt County, N. C., about 3 miles south of Parmele, N. C., on the Weldon and Kinston division of the Atlantic Coast Line Railroad. Mr. James said that when he discovered the vine growing in the woods it was only a few inches long with only one bunch of grapes. This bunch, however, had 9 or 10 berries, which were very large and remained on the vine in good condition for a long time. A grape with such qualities, he thought, should have attention so he determined to place it under cultivation.

While taking it up to transplant it to his home, a few hundred yards away, Mr. James accidentally broke it off, leaving only about 1 inch of root attached. The vine is still growing and covers an arbor about 20 feet in diameter. Mr. James died in May, 1907, and his son Charles now owns the old homestead and the original vine. (Pl. VIII, fig. 3.)

The soil in this section of North Carolina is a fine sandy loam with a clay subsoil and is considered a good, strong soil. Soils of this character, comprising a large portion of Pitt and Edgecombe Counties, produce a large proportion of the grapes now grown in the State, the James being the most extensively planted variety and is there usually considered superior to any other. Good cotton and tobacco crops are also grown in that region.

The general appearance of the James vines is similar to that of the Mish, the principal difference being in its habit of growth, which is more trailing, and the foliage, which is, perhaps, a little thinner and lighter in color. The vine is vigorous and productive and readily adapts itself to systematic training on an upright trellis. The leaf is cordate, with a serrate margin and averages $2\frac{1}{2}$ inches in width by $2\frac{1}{2}$ inches in length. In late summer the space between the prominent veins turns yellow long before the part next to the veins, giving the leaves a pronounced mottled yellow and green appearance not noted in other varieties at the same time.

The cluster appears large on account of the size and not the number of the berries. It contains from 2 to 12 berries, sometimes more, but usually 4 to 6 berries, is moderately compact, and round. (Pl. IX, fig. 2.) The stem is $1\frac{1}{2}$ to 1 $\frac{1}{4}$ inches in length. The berries are large, round, rather glossy, bluish or deep purplish black when fully ripe, with pronounced, though not very numerous, "guinea egg" specks. When not entirely ripe there is a rather characteristic reddish coloring around the peduncle. The berry is juicy, though the flesh is meaty, and the skin is thick and rather tough. The seeds are typical, adhering somewhat strongly to the pulp and averaging larger in size than those of other leading varieties. The flavor is of medium quality, the berries that ripen in the shade being of much better flavor than those ripening in the sun. The free-run juice is also superior.

The James variety is not grown much outside of North Carolina, although it appears to do well as far south as Florida. It probably ranks third in the quantity of fruit produced for all purposes and first in shipping qualities. It must have careful handling in shipping, and with care can be sent to northern cities with good results. The fruit resembles that of the Mish more closely than any other of the standard varieties, but is larger, rounder, glossier, and darker, less speckled, ripens earlier, is juicier, not so sweet, and has harder pulp. Its handsome appearance, juiciness, productiveness, fair quality, and good adherence to the peduncle make the James the best general-purpose variety of *Rotundifolia*.

Mish.

The Mish grape, according to Capt. George Brown, Walter A. Mish, and others of Washington, N. C., was discovered by Mr. Albert Mish between 1840 and 1850 growing in pure river sand, near the edge of the Pamlico River at Swans Point, 4 miles south-



FIG. 19.—Upper side of a Thomas leaf. (Natural size.)

east of Washington, N. C. (Pl. VIII, fig. 1), and was transplanted to his home, a short distance away. The vine grew and covered a large white-oak tree in front of Mr. Mish's residence, where it remained until a few years ago, when it was uprooted during a heavy storm. It was prized very highly from the time of its discovery and was soon distributed by Mr. Mish among his friends throughout eastern North Carolina. The soil where the vine was discovered is very sandy, varying from river sand to dry sandy loam. A fair growth of oak, pine, and other timber occupies the virgin soil and good crops of corn, cotton, and sweet potatoes are produced in the immediate vicinity.



CLUSTER AND LEAF OF THE FLOWERS GRAPE AND OF THE EDEN GRAPE.
(Natural size.)

The Mish vine resembles both the James and Flowers in general appearance, but is more like the James and is of about the same vigor. It has an upright habit of growth. The leaf is thick and rather round, with an average width of $2\frac{1}{4}$ inches and an average length of 3 inches.

It has a fair tendency to bunch and the berries adhere fairly well to the peduncle. The berries range from about eleven-sixteenths to three-fourths of an inch in diameter, are slightly ovoid, almost black, with numerous "guinea egg" specks, tender, juicy, and sweet. (Pl. XI, fig. 2.) The skin is medium thin, cracking in wet weather. The seeds number two to four and are of medium size, coming to a sharp point at the base. The fruit ripens just after the James. The flavor is distinct, delicious, and



FIG. 20.—Lower side of a Thomas leaf. (Natural size.)

of good quality. This variety is considered by wine men second only to the Scuppernon for wine purposes and is second only to the James as an all-purpose grape, but in yield it does not equal the James variety. It is regarded as the best grape of all in the district where it originated and is almost the only variety planted there. The crop ripens uniformly, a very good character for a wine grape, and this, together with a high sugar content, the character of the foliage, the size, shape, and markings of the fruit, its fine flavor, small seed, and fairly good adherence to the peduncle are distinguishing features.

Thomas.

The Thomas grape was discovered by Mr. Drewery Thomas between 1850 and 1855 growing near a springhead, 4 miles northwest of Marion, S. C., and about 1 mile from

Catfish Creek on what was then Mr. Thomas's land but which is now owned by Dr. W. W. Hamilton, of Marion, S. C. (Pl. VIII, fig. 2.) Mr. Thomas transplanted the vine to his home (now owned by H. C. Graham, of Marion, S. C.), a few hundred yards from where it was found. Mr. Thomas died several years ago, but the history of the variety is well established by Dr. W. W. Hamilton, Thomas Fore, and other citizens of Marion. There are at present several old arbors at the Thomas place and in all probability one of these is the original.

The soil where the vine originated is a fine sandy loam with a clay subsoil. The land was originally heavily timbered and produces good crops of corn, cotton, and



FIG. 21.—Upper side of an Eden leaf. (Natural size.)

sweet potatoes. The Thomas grape is said to be hardier and longer lived than the Flowers in this section. The vine and wood resemble the Scuppernong, differing mainly from it in that the young shoots and the petioles of the young leaves are darker, a little thicker, and more serrate. The width of the leaves is about 3 inches and their length about 3½ inches. (Figs. 19 and 20.) The growth is about the same. The clusters are rather small and very compact, with a short stem, too short to hold in picking the fruit. (Pl. IX, fig. 1.) The berries are of medium size, round, dark-wine color when fully ripe, and surrounding the base there is a wide, prominent greenish or yellowish irregular pentagonal marking. The flesh is tender, juicy, very sweet, and has an exceptionally rich, sprightly, and fruity flavor. The skin is thin and moderately



SCUPPERNONG



MISH

A. ROSEN & CO. BALTIMORE

A. Newton

CLUSTER AND LEAF OF THE SCUPPERNONG GRAPE AND OF THE MISH GRAPE

Natural size.

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tough with numerous small pimples dotting the surface. The seeds number three to four and are about the same size as those of the Flowers variety, but are more oval and flattened. The fruit ranks the highest of the Rotundifolia in sugar content, and those who know the variety prefer it to all other Rotundifolia varieties as a table grape. It makes a good wine. It is apparently, with the exception of the Scuppernong, the most widely distributed of the Rotundifolia varieties, but is not so extensively planted as the James, Mish, or Flowers, and is not grown in large quantities. It ripens very unevenly, the berries on the same cluster ripening several days apart. This and its poor adherence to the peduncle are strong objections to the variety.



FIG. 22.—Lower side of an Eden leaf. (Natural size.)

Often the first berries to ripen fall off before the later ones, even on the same cluster, are ripe. However, every home vineyard should have sufficient Thomas vines to supply the table, for it is recognized as the best table grape among the Rotundifolia.

Eden.

The Eden grape was discovered on the premises of Dr. Guild, east of Atlanta, Ga., and was introduced by Dr. Samuel Hape, of Hapeville, Ga. The soil in this region is the typical red clay of the Piedmont section and this variety is said to be well adapted to it. The Eden is the only variety of this group discovered in such soil. It is a remarkably vigorous grower, with dense foliage and dark-colored wood.

The leaves are of medium thickness, with wide basal sinuses similar to *Vitis munsoniana*, and while the other commercial Rotundifolia varieties have cordate leaves with sharp, jagged margins the Eden has rounded leaves with rounded marginal teeth and blunt tip. (Figs. 21 and 22.) The tip of the leaf is sometimes concave V-shaped, though generally convex and pointed, and it averages $2\frac{1}{2}$ inches in width by $2\frac{1}{2}$ inches in length. The bunch is also quite distinctive and resembles *V. munsoniana*, is very loose, containing from 5 to 25 berries and is cymelike, with a long stem breaking at a joint midway between the cane and berries. The clusters are easily gathered and the berries on individual clusters ripen uniformly, though the vines produce distinct first and second crops. (Pl. X, fig. 2.) The berries are round, about half an inch in diameter, dull black when first ripe, faintly speckled, and adhere fairly well to the peduncle. The flesh is soft, juicy, and colorless, with a pleasant flavor, though tart even when entirely ripe. The quality is very good, the skin is relatively thin and tender, and the seeds are small.

The Eden is adapted for wine, home, and kitchen use. It is remarkably productive and an excellent vine for arbors and summer houses. In the Rotundifolia experiment vineyard at Willard, N. C., it has yielded more than any other variety. It is also the most distinct in type, the earliest and most vigorous in growth, and one of the earliest to ripen. It is somewhat difficult to train on an upright trellis, because of the tendency of certain shoots to take the lead and crowd out all the others. There are many things about this variety which suggest both the Rotundifolia and Munsoniana, and it is possible that the Eden may be a natural hybrid between them. Some also think that it may be a natural hybrid between the Rotundifolia and a bunch-grape variety.

Memory.

The Memory grape was discovered between 1868 and 1870 by Col. T. S. Memory in his vineyard in the town of Whiteville, N. C. Col. Memory was a grape grower and owned a third interest in the old grape nursery of Ellis & Co., at Whiteville, N. C. About 1872 he bought out the firm and conducted the business under his own name until his death, in December, 1896. The firm handled the following varieties: The Scuppernong, Flowers, Thomas, Tenderpulp, Sugar, and, later, Mish, Memory, Pee Dee, and Flowers Improved. Col. Memory propagated the Memory variety extensively and distributed it over the entire Rotundifolia territory, especially in North Carolina, Georgia, and Texas. It grew up under a Thomas vine, resembles the Thomas variety in many respects, and is probably a seedling from it. The discoverer, in a pamphlet describing the variety he had for sale, said:

Memory was discovered since the late war in my vineyard among some Thomas grapevines, and no doubt is a seedling of the Thomas; is much larger than Thomas; ripens in September. It is much sought after where it is known.

After the death of Col. Memory the vineyard passed into the hands of his son, Mr. J. L. Memory, who was not interested in grape growing at the time and destroyed nearly all the vines, including the original Memory vine. Later he became interested in grape culture, and is now growing plants from a large vine at Whiteville which was propagated directly from the original and now belongs to his sister. The original Memory vineyard was on an elevation about 15 miles from the place where the Flowers variety originated, the soil being typical Coastal Plain sandy loam underlain with clay.

The vine is quite vigorous. It holds its foliage better than most varieties during drought and also well into the fall. The leaves are of medium size, averaging $2\frac{1}{2}$ inches in width by $3\frac{1}{2}$ inches in length. They are cordate, quite pointed, with a margin medium serrate, rather thick, dark, and leathery. The first fruit ripens about August 10 in Florida and about September 1 in North Carolina. The cluster is round, fairly compact, and consists of from two to eight berries, which adhere to the peduncle

until they shrivel. The berries are slightly oval, measuring about $\frac{3}{8}$ to $\frac{1}{2}$ by $\frac{1}{4}$ to 1 inch. They are black, with a reddish coloring next to the peduncle when not fully ripe, and sometimes with rough, irregular, russet spots upon them. The flesh is white, with a medium juiciness and pulpiness. The flavor is excellent, sweet, and of good quality. The skin is rather thick and tough, and there are two or three medium-sized seeds. The vine is very productive. The Memory variety stands shipment well and is an excellent table, kitchen, and wine grape. Where it is known

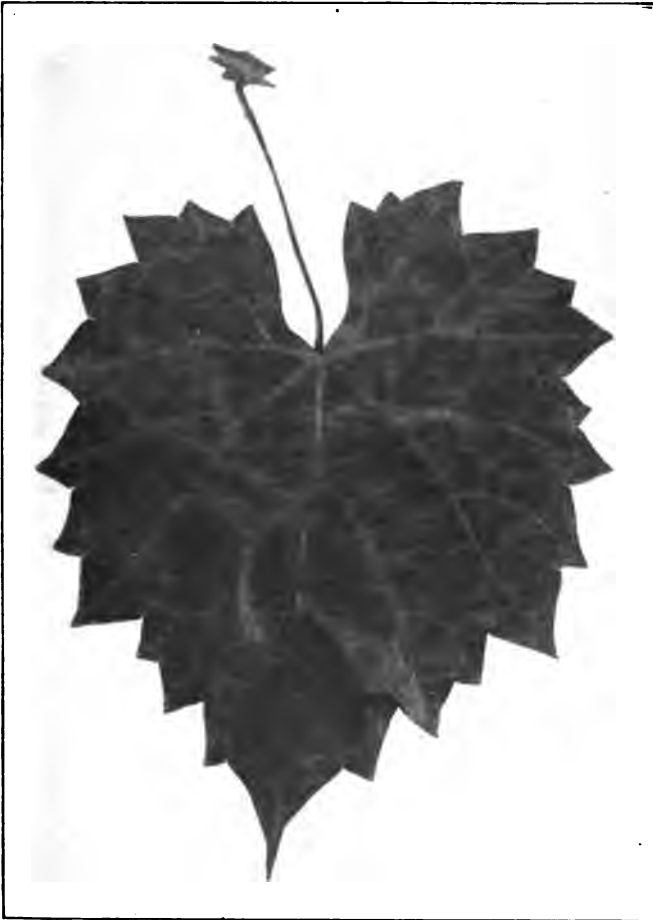


FIG. 23.—Upper side of a Luola leaf. (Natural size.)

in Florida it is considered the best all-round black variety and deserves to be much more extensively grown. Its fine flavor and good shipping qualities are its two best attributes.

Hopkins.

The exact origin of the Hopkins grape is not known. From what can be learned it is supposed to have originated near Wilmington, N. C., and the oldest known vine, supposed to be the original, is on Mr. W. B. McClellan's farm, about 2 miles northeast of that city. This vine is healthy and vigorous, with large, dark-green, thick,

broadly cordate, irregular, dentate leaves. The clusters have small, easily detached stems and resemble those of the Scuppernong. The berries are large, five-eighths of an inch to $1\frac{1}{2}$ inches in diameter, black, and slightly oblong. The flesh is pulpy but soft, with a flavor that is sweet and pleasant. The skin is medium thick and tough, and there are from two to four large seeds. The vine is very productive. The fruit ripens very early, generally about the last of August at Wilmington, N. C. This variety has been extensively grown by Mr. Ollen E. Warren, of Greenville, N. C., who has in his collection the Flowers, Mish, James, and Scuppernong varieties, besides



FIG. 24.—Lower side of a Luola leaf. (Natural size.)

the Hopkins, and the Hopkins appears to be the healthiest and most vigorous of them all. Its vigor, flavor, earliness, size, and the appearance of the berry are its distinguishing features.

Luola.

The Luola variety was discovered 20 or 25 years ago by Mr. G. W. Lennon's father, on his place 6 miles northeast of Boardman, 14 miles northwest of Whiteville, and 17 miles southeast of Lumberton, N. C., about 8 miles from where the Flowers originated, and about 30 yards from Oakley Branch. It is still growing where it was discovered, and it, together with some young vines in the cooperative Rotundifolia experiment

vineyard of the Department of Agriculture, and two young vines at Lumberton, N. C., are all there are in existence. This grape closely resembles the Tenderpulp, but ripens later, is of better flavor, and hangs on until frost. The leaves are cordate, pointed, broadly serrate, and are above medium size, being $2\frac{3}{4}$ inches in width by $3\frac{1}{2}$ inches in length. (Figs. 23 and 24.) The clusters are of medium size, rather loose, with berries of a dark purplish black, round, melting, juicy, fruity, and vinous. The skin is thin and tender and the seeds small. This variety ripens just before frost.

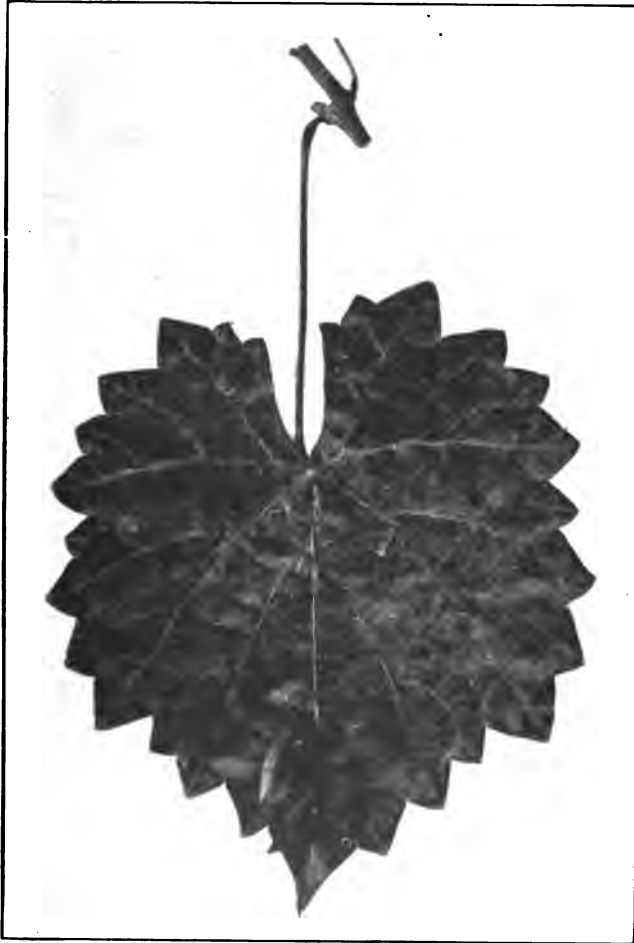


FIG. 25.—Upper side of a Smith leaf. (Natural size.)

The soil where this variety originated is a fine sandy loam, with clay subsoil and resembles the Chadbourn strawberry soils. The Luola differs from all other known *Rotundifolia* varieties in its very tender skin and small seeds.

Smith.

The Smith, sometimes called Smith's Improved, was discovered growing on light, sandy soil by Mr. C. J. Smith, of Alberston, Duplin Co., N. C., about 20 years ago. The original vine is still standing, the timber, which was of medium growth, hav-

ing been cleared away from around it. Mr. Smith has several arbors of it. At Kinston, N. C., it is considered a very fine grape for home use. The vine is vigorous and productive, upright, but rather trailing in its habits. The leaves are cordate, rather thick, and not much pointed. (Figs. 25 and 26.) The clusters are of medium size and roundish; adherence to peduncle very good. The berries are $\frac{7}{8}$ by 1 inch in diameter, oblong, bluish or deep purplish black, and when fully ripe have very distinct "guinea speck" markings. The skin is tough and the seeds fewer in number

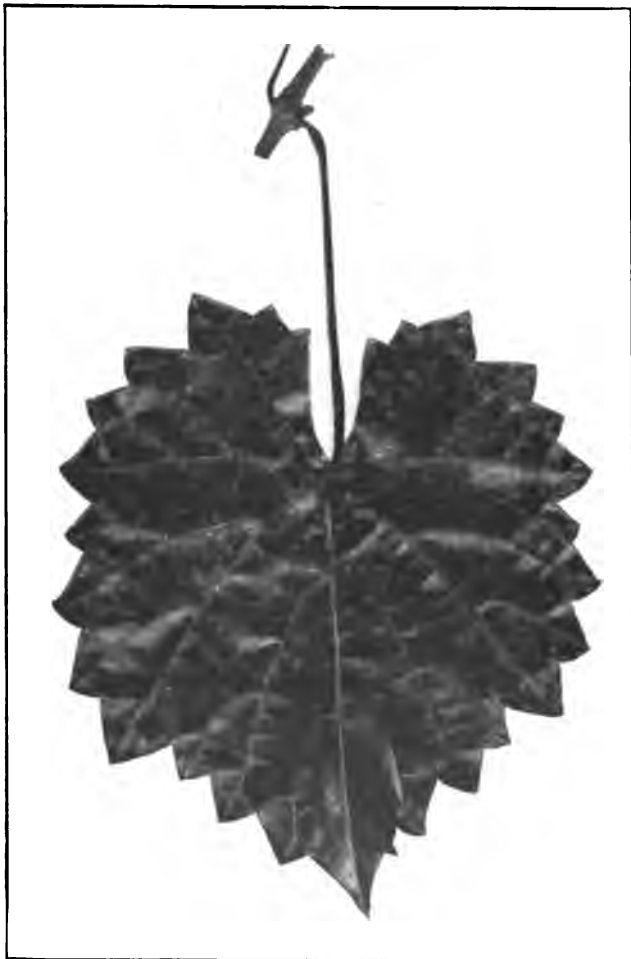


FIG. 26.—Lower side of a Smith leaf. (Natural size.)

than in most varieties. The Smith ripens early, hangs on the vine until frost, and is considered a good shipping variety. The fruit resembles the Memory.

Lady James.

The Lady James grape was discovered about 25 years ago, by Mr. B. M. W. James, of Grindool, Pitt Co., N. C., who also discovered the James grape. It grew near his vineyard and Mr. James supposed it to be a seedling of the James, but because of its more refined qualities and texture named it the Lady James. Its fruit resembles

the Thomas very closely in every respect. The clusters are of medium size and very compact, with a short stem, making it hard to pick. It has berries of medium size, round, and of a reddish wine color when fully ripe, with prominent greenish or yellowish pentagonal markings at the peduncle. The skin is thin and moderately tough, with numerous small pimples dotting the surface. The fruit is juicy and sweet, and the flavor sprightly. The vine has an upright but rather trailing growth. The fruit is recommended for home use only.

Latham.

The Latham was discovered by F. P. Latham, before the Civil War, 3 miles from Newbern, N. C., near where Brook Creek empties into the Neuse River, and the original vine is believed to be from 55 to 60 years old. Mr. Latham transplanted it to his home on the other side of the Neuse River, 2 miles from Newbern.

This grape closely resembles the Thomas and Lady James in growth, habit, and character of fruit. It is propagated to some extent in that section, being esteemed as a dessert and wine grape. The clusters are compact and of medium size. The stem is very short, holding the cluster closely to the cane. The berries are of medium size, round, of wine color, with prominent pentagonal markings on berry at the peduncle. The skin is thin but moderately tough, sprinkled over with pinhead dots. The fruit is juicy, exceedingly sweet, and of a sprightly flavor. Mr. Latham says that this grape tests higher in sugar by $2\frac{1}{2}$ per cent than any other variety in that section. The soil around the Latham home is sandy to loamy and is slightly above the water line. The land is usually heavily timbered and appears well adapted to the growth of grapes.

Pee Dee.

The Pee Dee was first brought to notice by Dr. H. Williamson in the early sixties, and is said to be a chance seedling discovered at Darlington, S. C. It was for a time listed in the catalogue of the P. J. Berckmans Co., of Augusta, Ga., but has now been discarded by them. The only known vines of the variety are to be found near Darlington. Pee Dee is of interest because it is a white-fruited variety of *Rotundifolia* known to be distinct from the Scuppernong. The fruit is smaller and ripens later, but otherwise is similar to the Scuppernong. The Pee Dee is recommended for home use only where a late white variety is desired.

Sugar.

The Sugar, sometimes called the Sugar Pulp, is thought to have been discovered near Whiteville, N. C., by the late Col. T. S. Memory, who discovered and introduced the Memory grape. The Sugar was distributed about 1900 by Ellis & Co., the firm of which Col. Memory was a member. There are a few vines located at various places in North Carolina. The largest plantings are those of Mr. E. C. Carraway, 9 miles from Kinston, and Mr. H. L. Pritchard and Mr. R. Elliott at Skinnerville, N. C. This variety can not be recommended for general planting. The following is a brief description of it:

The vine is rather vigorous, productive, and upright, with a cordate, regularly dentate leaf. The cluster is round and of medium size with round, sleek, black berries five-eighths to seven-eighths of an inch in diameter. The flesh is soft, not very sweet, fairly juicy, and of medium quality. The skin is thick and tough, and the seeds large. This variety ripens about October 1 in North Carolina and is in season until frost.

Carolina Belle.

The Carolina Belle was planted by Mr. Elisha Lamb 18 or 20 years ago on his estate, which is now owned by Mr. W. K. Hindreen, of Dwight, N. C. It is thought to be a chance seedling that came up near some hogpens on Mr. Lamb's place. The variety is of small commercial importance, but is propagated to some extent near Dwight, N. C. The vine is a very rapid, distinctly upright, open grower. The leaves are cordate, sharp pointed at tip, have a sharp, serrate margin, are medium dark green, glabrous, and leathery. They vary in size, but average from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in length. The clusters are of fair size, with berries of medium size, oblong, almost black, with

frequent small specks, fairly juicy, and of medium quality. The skin is thin but tough and the seeds small. The Carolina Belle ripens two weeks earlier than the Mish, but is inferior to it in quality.

Beula.

The Beula grape originated about 40 years ago as a chance seedling in the vineyard of the late Benjamin F. Meekins, at Manteo, N. C. The old vine, erroneously called the "Original Scuppernong," and said to have been set out by Sir Walter Raleigh, is located in the same vineyard. Mr. Meekins had four or five arbors of the Beula at the time of his death in 1909, considering it a valuable grape. After its discovery the variety was brought to notice by Mr. Fred Proctor, of Manteo and Elizabeth City, N. C., who died about 15 years ago. The vine is a vigorous to rank grower and is upright and branching, with brown canes and dense foliage. The leaves are of medium size, averaging 2½ inches in width and 3¼ inches in length, dark green, cordate, and have a medium serrate margin. The cluster is round and of fair size, with large brownish black berries, flattened at base, meaty but juicy, and of medium flavor and quality. The skin is thick and tough and the seeds typical. We have never seen this variety growing anywhere except at the Meekin place and at the Medoc Vineyard, Enfield, N. C. The Beula is very productive, but is suited only for wine, and there are other varieties that surpass it for this purpose. It can be easily recognized by its large dorso-ventrally flattened berries.

Tenderpulp.

The Tenderpulp was discovered by Mr. D. P. High at Whiteville, N. C., about 1868, growing in his vineyard as a chance seedling. It soon fell into the possession of nurserymen and was quite generally distributed. Mr. High himself never considered the variety worth planting and the writers do not recommend it. It is superior to the wild grapes only in its tenderness of pulp; even in this respect it is inferior to several other varieties and is not of sufficient importance to warrant a description.

Clayton.

The Clayton grape in some respects resembles the James, in others the Mish variety. It was found by Col. Clayton Griffin on Swans Point within 50 yards of where the Mish vine was discovered and transplanted to his home, where the original vine now is. Mr. Griffin is dead, but the place is still owned by his widow, Mrs. Ellen Griffin. The variety has never been tested and at present does not warrant a description. It is, however, a good variety and deserves further trial.

Westbrook.

The Westbrook grape originated as a chance seedling at the home of the late Mr. J. S. Westbrook, at Faison, N. C. When Mr. Westbrook moved to Wallace he took some plants with him. The variety is now grown to a limited extent, but is not considered of sufficient importance to warrant a description.

Brown.

Mr. J. I. Brown, of Kinston, N. C., has a small reddish variety of *Rotundifolia* which he has named the Brown grape. It is a seedling that came up about 15 years ago on an old breastwork near by. Both vine and fruit are similar to the Scuppernong, the fruit being, perhaps, sweeter, a little better in quality, and thinner skinned. The berry is smaller and ripens later and is, perhaps, more inclined to cluster. This variety is being tested in a small way in the *Rotundifolia* experiment vineyard.

San Jacinto and other hybrids.

Prof. T. V. Munson, Denison, Tex., has introduced several hybrids, of which the San Jacinto is the best known. The San Jacinto and the La Salle are the result of crossing the Scuppernong with a Post Oak variety, and the others, Dixie, Howard, Labama, Marvel, "R65 No. 5," "R66 No. 11," Sanbrilasco, San Gabriel, Sanherbo, Sanalba, Sanrubra, Sanmelaska, and Sanmonta are all crosses between the San Jacinto and the Brilliant or the Herbemont. As yet these varieties are of interest only from a plant-breeding standpoint.

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Issued April 8, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 274.

B. T. GALLOWAY, *Chief of Bureau.*

WILD WHEAT IN PALESTINE.

BY

O. F. COOK,

*Bionomist in Charge of Crop Acclimatization
and Adaptation Investigations.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 7, 1912.

SIR: I have the honor to transmit herewith a paper entitled "Wild Wheat in Palestine," by Mr. O. F. Cook, Bionomist of this Bureau, and to recommend its publication as Bulletin No. 274 of the Bureau series.

This paper contains a further account of the new cereal discovered by Mr. Aaron Aaronsohn, director of the Jewish Agricultural Experiment Station at Haifa, Palestine, and described by him in Bulletin No. 180 of this Bureau, entitled "Agricultural and Botanical Explorations in Palestine," which was published in 1910. The existence of a new type of wheat growing in a wild state was a matter of so much interest that Mr. Cook was instructed in 1910 to make a further investigation of the subject in connection with a visit to Egypt for the study of certain problems in the breeding of Egyptian cotton.

Though the present paper does not attempt to reach a final decision on the question whether the wild wheat of Palestine is the true ancestor or prototype of the domesticated varieties of wheat, it brings out several additional facts regarding the characters and habits of the plant, including the presence of specialized adaptations to facilitate cross-fertilization. This has an important bearing upon heredity and breeding because of the general theories and methods that have been based on the fact that many cultivated varieties of cereals have habits of self-pollination. The possibility that acclimatization and selection may develop improved varieties of the wild wheat worthy of cultivation for grain or forage is indicated by the results of an experimental planting in southern California. Another practical suggestion is the acclimatization of cross-fertilized forms of the domesticated type of wheat as a means of securing greater vigor, hardiness, and resistance to disease in the Southwestern States, where the self-fertilized European wheats often succumb to adverse conditions.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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WILD WHEAT IN PALESTINE.

INTRODUCTION.

Tracing the origins of cultivated plants is one of the most interesting branches of botanical geography. To learn where a plant like wheat was domesticated is to locate one of the milestones of human progress in remote prehistoric times. The adoption of fire and the domestication of plants gave primitive man an agricultural status and thus made possible the development of the other arts and institutions of human society. On account of the instinctive superstitious conservatism everywhere manifested among primitive peoples, it is reasonable to believe that the early stages of progress toward civilization were extremely slow and gradual and required many thousands of years.

That any definite knowledge is still to be gained regarding events that were forgotten long before human records began may seem quite impossible. But modern science finds methods of approach to many mysteries that were inaccessible to former generations. Space and time do not prove to be insuperable obstacles to scientific investigation. The astronomer projects his knowledge millions of miles into the heavens, to learn the motions and determine the composition of the stars. Biological relations of facts are as real, if not as definite, as the physical relations applied in the telescope and spectroscope.

The similarities of different species of plants and animals are not meaningless approximations or coincidences, but afford evidences of common ancestry and previous geographical association. It is as reasonable to look for related plants in adjacent regions as for related people in the same neighborhood. It is true that some species have been able to attain a very wide continental or cosmopolitan distribution, and especially those that have taken advantage of human assistance, like the weeds that infest cultivated lands. But even such plants usually have localized relatives from which the original center of distribution may be learned.

In addition to their historical and ethnological interest, the wild relatives and ancestral forms of our cultivated plants are also of practical value in relation to agriculture. Unless the ancestral form and wild relatives of a domesticated species are known it is impossible

to understand what the effects of breeding and cultivation may have been or to determine the possibilities of further improvement.

The wheat plant has served as the chief example of reproduction by self-fertilization. Many writers on heredity have considered self-fertilization as a normal condition and have made it the basis of general theories of heredity. Methods deduced from such theories have been widely recommended for the breeding of varieties of plants and animals, and even for the improvement of the human race.

The chief object sought in studying the behavior of wild wheat under natural conditions was to learn whether it was adapted to cross-pollination or limited to fertilization by its own pollen and whether there was natural individual diversity (heterism), as in other wild plants, or uniformity, as in self-fertilized or artificially selected varieties.

The present report is based on observations of wild wheat in its native habitat in the months of June and July, 1910. The visit to the wild-wheat country was made in connection with an investigation of cotton culture in Egypt, as reported in a previous publication.¹

The season proved to be too far advanced to afford a really favorable opportunity for the study of the wild wheat, and the time that could be devoted to this purpose was too short to make any complete study of the facts that could still be observed. Nevertheless, it was possible to secure quite definite evidence on the chief questions. All doubts of the status of the plant as a normally cross-fertilized wild species were resolved. This was shown, not only by the wide range of individual diversity, but by the presence of several specialized adaptations to facilitate cross-pollination.

In addition to the description and discussion of facts observed during this visit to Palestine, several further observations by Mr. Aaronsohn are included in the present paper. Any such examination of the wild wheat in the short time available would have been quite impracticable without the advantage of his previous study of the plant² and familiarity with the country, to say nothing of the hospitality and facilities of travel provided by him and his family.³

¹ Cook, O. F. Hindi cotton in Egypt. Bulletin 210, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1911.

² Aaronsohn, A., and Schweinfurth, G. Die Auffindung des wilden Emmers (*Triticum dicoccum*) in Nordpalestina. In *Altneuland Monatschrift für die Wirtschaftliche Erschliessung Palästinas*, Berlin, July-August, 1906, nos. 7-8, p. 213-220.

Contribution à l'histoire des céréales. Bulletin de la Société Botanique de France, vol. 56, 1909, p. 196-203, 237-245, and 251-258.

Agricultural and botanical explorations in Palestine. Bulletin 180, Bureau of Plant Industry, U. S. Dept. of Agriculture. August, 1910.

Wild dry-land wheat of Palestine and some other promising plants for dry farming. The Dry Farming Congress Bulletin, vol. 3, no. 3, Feb. 1, 1910, p. 161.

See also Schweinfurth, G., Ueber die von A. Aaronsohn ausgeführten Nachforschungen nach dem wilden Emmer (*Triticum dicoccoides* Keke.). In *Berichte der Deutschen Botanischen Gesellschaft*, vol. 26a, pt. 4, 1908, p. 300-324.

³ Mention is made in footnotes of a few recent observations by Mr. Aaronsohn, communicated during a visit to Washington while this bulletin was being printed.

BIOLOGICAL SIGNIFICANCE OF WILD CEREALS.

A special interest may be claimed for the biology of the wheat plant since no other plant can be said to have had so great an influence on the theory and practice of breeding. In what other line of plant breeding can any such series of notable successes be enumerated as those of Le Couteur, Sheriff, Vilmorin, Hays, Garton, Spillman, Nilsson, Tschermak, and many others who have developed new varieties of wheat and new refinements of the art of selection? Indeed, it might almost be said that plant breeding is based on the wheat plant, since a very large part of the interest in breeding relates either directly to the improvement of wheat varieties or to the application of the same methods to other plants. Even general theories of plant breeding seem to have been deduced largely from the biology of the wheat plant.

As long as no wild prototype or close relative of the wheat plant was known, it could be maintained that the habit of strict self-fertilization, as shown in cultivated varieties of wheat, represented the normal method of reproduction. Uniform self-fertilized strains of wheat and other cultivated plants have accordingly been considered by many investigators as representing the true nature of species and used as standards of judgment in the further study of the factors of heredity and evolution.

If each uniform variety is to be looked upon as a distinct elementary species it is equally logical to consider each abrupt mutative variation that comes true to seed as representing the origination of a new species. These ideas form a part of the theory of evolution by sudden mutative changes of one species into another, which some modern writers on heredity would substitute for Darwin's idea of evolution by gradual changes of the characters of species.

With a plant as definitely restricted to self-fertilization as the cultivated varieties of wheat are supposed to be, the tasks of individual selection, testing of progenies, and increase of superior strains are reduced to an ideal simplicity. When cross-pollination is prevented by the structure and habits of the plants the difficulties of isolating varieties to prevent crossing in the field do not arise. Different varieties and individual selections from the same stock may be planted side by side without danger of crossing, and the same plantings may serve the double purpose of breeding and testing. The only precaution is to avoid the admixture of different stocks of seed.

But with cross-fertilized plants, like Indian corn or cotton, the methods that have been used for wheat breeding are entirely inadequate. Each stock must be isolated, either by planting in a separate place where the pollen of other varieties will not be carried by the wind or by insects, or artificial pollination must be performed and

foreign pollen excluded. Without these additional precautions the methods of breeding that improve the wheat crop are entirely inadequate, or even dangerous, when applied to superior strains of cross-fertilized plants. To overlook the difference between self-fertilized and open-pollinated plants not only permits inadequate general theories to be framed but leaves out of account some of the most serious difficulties in breeding.

The convenience of self-pollinated plants for breeding experiments should not be taken as proof that restriction to self-fertilization represents a normal biological condition. The preponderance of biological evidence indicates that the crossing or uniting of different lines of descent has a physiological function in maintaining vigor and fertility.

Some writers have supposed that plants like wheat constitute a separate class where crossing does not have its usual significance and self-pollination is the normal condition. Breeders and students of heredity are divided between three general theories or schools of opinion—one which accepts self-fertilization as the normal and ideal condition, another which accepts cross-fertilization, and a third which accepts both conditions and advocates a dualistic or double theory, crossing being assumed as normal for some plants but not for others. The wheat plant has served thus far as the most important example of self-fertilization. For this reason the habits of pollination of the wild relatives or ancestral types of wheat command a general interest in relation to the whole philosophy of heredity, as well as a special interest in relation to the breeding of this most important cereal.

The wild prototypes and relatives of wheat are also likely to have direct value for breeding purposes. Crossing these with our domesticated varieties may be expected to lend increased vigor, hardiness, or other desirable characters. Other possibilities lie in the direction of acclimatization or domestication of new forms that are more desirable or better adapted to particular conditions. It is not surprising that European varieties of wheat should not thrive in our Southwestern States. The selective improvement of a variety in England, France, or Germany might reduce or exclude the very characters that would be needed to adapt the plant to our Southwestern conditions. It is not to be supposed that primitive man chose in all cases the best plants for domestication or that the forms that happened to be selected are the best for our present needs.

A GENUINE WILD WHEAT IN PALESTINE.

One of the chief difficulties in tracing the origins of cultivated plants arises from the fact that many domesticated species have escaped from cultivation and resumed their wild state in different parts of the

world, often in regions remote from their original habitats. In as old a country as Palestine there certainly has been no lack of opportunity for wheat to escape from cultivation and establish itself as a wild plant, if it were capable of doing so.

Though the total area of cultivation was probably greater in some of the more prosperous epochs of former times, wheat is still grown over nearly the whole country. The natives often climb to remote and almost inaccessible places to plant a few square yards of wheat. The deserted courts and chambers in the ruins of the fortress of Cæsarea Philippi on the pinnacle of a mountain spur above Banias are still planted every year with wheat in much the same way that the Indians of Central America use the terraces and walled inclosures of the ruins of Rabinal, Quiche, and Ocosingo for the planting of corn. The soils about these ancient ruins seem to have a perennial fertility, either because they represent the débris accumulated by former populations or because of exceptional natural fertility that attracted the primitive inhabitants and favored the development of centers of civilization in ancient times.

The native methods of harvesting and carrying home the unthrashed wheat on the backs of donkeys and camels are well calculated to scatter the seed along all the footpaths of the country, and this probably accounts for the frequent occurrence of apparently spontaneous plants of the domesticated type of wheat. A little careful searching in almost any locality is likely to reveal the existence of scattered wheat plants growing spontaneously by the roadside. This is true of the districts where the wild wheat abounds, as well as of other parts of the country.

Yet there is not the slightest indication that the wild wheat owes its existence to this scattering of the seed of the domesticated wheat. In spite of abundant opportunities it does not appear that domesticated wheat has anywhere made good its escape from cultivation. It is not known in any place as a genuine wild plant, but usually remains limited to the roadsides and to lands recently cultivated, being unable, apparently, to hold its own in competition with native vegetation.

The wild wheat, on the other hand, not only maintains an existence without any human aid, but occupies large areas altogether too rocky and broken to admit of agricultural occupation. (See Pls. I and II.) In such places it often appears as the dominant grass, showing itself abundantly able to hold its own in competition with other forms of vegetation. This supremacy may be explained, at least in part, by the specialized adaptive characters that are to be discussed in a later chapter of this bulletin.

The possibility of the wild wheat representing an escaped form of the cultivated wheat was also considered from the standpoint of

heredity. Spontaneous plants of the domesticated type of wheat were examined at every opportunity, and specimens collected and compared to see whether they showed any approximation to the wild type. No indication was found that the domesticated wheat when growing spontaneously, even under the most unfavorable conditions, has any tendency to revert toward the characters of the wild plant. (See Pls. III and IV.)

Nor does the wild wheat, when it finds more prosperous conditions in cultivated fields, show any tendency to lose its distinctive peculiarities and take on those of the cultivated wheat. The plants become much more luxuriant, with wider leaves, more numerous stalks, and larger heads than are usually shown in uncultivated land, but the essential differences of structure and habits are not lost or even appreciably diminished.

The determination of the status of the plant as a genuine wild species is entirely distinct from the question whether the wild wheat represents the true ancestral form or prototype of domesticated sorts. That the plant is a true wild species can hardly be doubted by anyone who has observed its characters and habits of growth under its native conditions and compared them with those of the cultivated and spontaneous forms of the domesticated species. A final solution of the prototype problem requires a different kind of evidence. As Mr. Aaronsohn has pointed out, the characters of the wild wheat of Palestine correspond in a remarkable manner to those that had been predicted for the prototype of cultivated wheats by Koernicke and other eminent authorities in the study of the cereals. Yet much experimentation with and study of both wild and cultivated wheats may be necessary before the prototype question can be definitely settled.

The prototype question becomes all the more interesting because the existence of a genuine wild type of wheat in Palestine can be certified. If the Palestine wheat can be accepted as the prototype, it will make possible a most interesting and important determination of the extent to which the characters and habits of the wheat plant have been modified in domestication. On the other hand, if the Palestine plant is not the true prototype of domesticated wheat, but an independent species, it will still have very great scientific and practical interest as the nearest collateral relative of cultivated wheat thus far known in a wild condition.

Specialists in the study of cereals may consider it desirable to describe the Palestine plant as wild emmer instead of as wild wheat, but this is calculated to obscure the true interest of Mr. Aaronsohn's discovery. "Emmer" is not an English word and can be made intelligible to the general reader only by defining it as a kind of wheat.

Spelt also is always considered as a type of wheat, though it has less similarity than emmer to the more familiar forms of wheat. There is no word but "wheat" to serve as a general name for the cereal grasses that belong to the genus *Triticum*.

To call the wheat "wild emmer" is also misleading, or at least premature, for it involves the idea that the wild plant of Palestine is to be associated definitely with emmer and not with other kinds of wheat, which has not been shown and may not be true. Koernicke's changes of botanical treatment in identifying the wild plant first with the einkorn wheat (*Triticum monococcum*) and then with the emmer wheat (*Triticum dicoccum*) shows how uncertain he was regarding the true affinities of the new type, which probably belongs to neither of these species. Both the emmer and the einkorn lack the most characteristic features of the wild wheat, the elongated kernels and the lateral articulations of the joints of the rachis. The articulation of the wild wheat is the most specialized of any of the plants in question. The narrowed base of the joint is not attached at the end, as in emmer and einkorn, but on one side, as in the wild barley. The joints of emmer not only break off at the end, but the point of insertion into the next joint below is in a distinct pit, the outer rim of which is produced into a broad, angular tooth, not present in the wild wheat.

In view of the fact that the Palestine plant has a definite status as a wild species, it would have been better to give it an independent specific name than to treat it as a mere varietal appendage of a domesticated form. The presence of two seeds in the spikelets, which suggested Koernicke's name *dicoccoides*, is a superficial and variable character, and the subspecific name *dicoccoides* becomes absurdly tautological when used in the combination *Triticum dicoccum dicoccoides*. It is fortunate in such a case that the rules of botanical nomenclature do not require the retention of the previous varietal name when a plant is recognized as a distinct species. This makes it possible in the present instance to avoid further misunderstanding by giving the wild wheat of Palestine an independent specific name. For this purpose the new name *Triticum hermonis* is suggested, to commemorate Mr. Aaronsohn's discovery of the plant in the region of Mount Hermon.

ADAPTATIONS FOR CROSS-FERTILIZATION.

EXserted ANthers AND OPEN GLUMES.

Though self-fertilization has been generally accepted as the normal habit of the wheat plant, some observers are inclined to think that natural crossing may take place frequently, either by insects or by

wind-borne pollen. Though the flowers are not visited by bees or other large insects that carry pollen for other plants, the general presence of thrips in wheat flowers forbids any general assumption of a total absence of cross-pollination, as pointed out by Mr. Luther Burbank in conversation several years ago. It is conceivable that in the natural home of the wheat plant thrips or some other small insect might act as a regular agent of cross-fertilization. Although this would represent a very specialized condition in a member of the grass family, it would not appear as improbable from a general biological standpoint as the complete absence of crossing that some writers have been willing to assume.

In Palestine, as in the United States, thrips is a very common insect in the wheat fields and could reasonably be expected to carry occasional grains of pollen from one flower to another. But in Palestine it does not appear that either the wild or the domesticated wheat is dependent on thrips or other insects for cross-pollination, for both plants share the ability of other wind-pollinated grasses to extrude the anthers and expose the stigmas. The extrusion of the anthers scatters pollen upon the wind and the spreading of the glumes admits pollen to the receptive stigmas.

That the stigmas do not project outside the glumes is not to be taken as an evidence against cross-fertilization, but is rather to be considered as an adaptation to favor crossing in a desert climate where pollination is often endangered by the shriveling of stigmas by dry winds. Thus the drying of the silks before fertilization can take place is one of the chief difficulties in the production of Indian corn in dry climates. The stigma of the wheat plant is a very delicate, many-branched, mosslike structure that requires protection from drying, but is extremely well adapted to catch any grain of pollen that may fall into the chamber where the stigma lies hidden between the protecting glumes.

With the glumes of the wild wheat in their usual closed position the chance of a wind-blown grain of pollen falling in between them would be very small, and at first it did not appear that any large quantity of pollen was available for distribution by the wind. Though many extruded anthers were visible, examination with a lens showed that most of them were completely empty. Many of them belonged to flowers whose stigmas had evidently been fertilized several days before, for the seeds were already well developed. In some cases it seemed that the empty anthers were being pushed out from between the glumes by the elongation of the young kernels. The finding of well-developed seeds in spikelets that had never emerged from the inclosing sheath also showed that the wild wheat, as well as the domesticated, is undoubtedly capable of self-fertilization.

Wind pollination, it seemed, might be a very small factor, notwithstanding the exertion of the anthers.

But such inferences would have been erroneous, because the first observations were made too late in the day. When a better opportunity was finally secured, so that a study of the behavior of the wild-wheat flowers could be made early enough in the morning, a very different impression was gained. Some of the plants showed many freshly extruded anthers hanging on long filaments and just beginning to scatter their pollen. On other plants there were flowers with the glumes spread wide apart, ready to receive the pollen. The glumes separate at angles of about 30° or 40° , forming a broad tube or funnel with the expanded stigma at the bottom. Though well protected on all sides, the stigma can be seen by looking in from above. (See Pl. V.)

In other cases young, unripe stamens were found in open flowers along with apparently adult, receptive stigmas. These flowers were obviously protogynous, the stigmas being ready for fertilization well in advance of the ripening of the stamens. Two pollen grains were seen on the branches of the stigma of one of these open flowers whose anthers were still very young and green. Though it could not be certified that the grains were wheat pollen, their presence left no doubt that the stigmas were accessible to pollination from adjacent wheat plants whose exerted anthers were then scattering pollen. The production of very regular, well-filled seed heads may also be taken as an indication that cross-pollination is usually accomplished, though there is a possibility that the stigmas of protogynous flowers remain receptive long enough to enable them to be fertilized from the anthers of the same flowers, in the event that no foreign pollen arrives.

Students of flower pollination have long been aware of the fact that the opening of the glumes makes it possible for the flowers of the wheat plant to be cross-pollinated.¹ But breeders and writers on heredity have taken little account of such facts, perhaps because most of them lived in northern climates, where cold or wet weather often prevents the opening of the flowers. The possibility that cross-fertilization might represent the ancestral condition has not been considered.

The finding of what appears to be a natural hybrid between wild wheat and *Aegilops* may be considered as a further indication that natural conditions are not unfavorable for crossing. *Aegilops* is another grass that was formerly considered by some writers as the wild prototype of wheat. As one of the species, *Aegilops ovata*, has been crossed artificially with domesticated wheat, some botanists

¹ Knuth, P. Handbook of Flower Pollination, translated by Davis, vol. 3, p. 529.



FIG. 1.—Young head of wild wheat with exserted anthers. (Natural size.)

unite *Aegilops* with *Triticum* instead of treating it as a distinct genus. Only a few spikelets of the supposed hybrid were found, and these all in one spot, very likely from the same parent plant. Mr. Aaronsohn considers them as undoubtedly representing a hybrid, an opinion which his long familiarity with the wild wheat and the Syrian forms of *Aegilops* would give him the best of qualifications to pronounce. The characters of the hybrid are definitely intermediate in the structure of the head, the rachis, and the beards, as well as in the characters of the spikelets themselves.¹ (See Pls. VI and VII.)

INDICATIONS OF SEXUAL DIMORPHISM.

That the wild wheat plant may be dimorphic with reference to the behavior of the stamens and anthers, is a possibility worthy of consideration in further investigation of this subject. At the end of June the season was too far advanced to permit an adequate study to be made, for nearly all the plants had passed beyond the flowering stage. It was only in cases where the wild wheat had invaded cultivated lands and was able to produce large, many-stooled plants that there were enough young heads to serve as a basis of comparison of the behavior of different individuals in these respects. In two or three places where such comparisons were possible it was noticed that on some plants all of the young heads showed pendent, exserted stamens. (Fig. 1.) Other plants showed no well-exserted stamens, but only such as might have been pushed out by the elongation of the developing pistil. The former may have represented a proterandrous caste, the latter a proterogynous or autogamous caste. At least, these differences indicate a wide range of variation in the relative age and time of maturity of the stamens and pistils.

One spikelet with open glumes was found on a head of wild wheat that did not appear to be very young, but the stigma was still fresh, as though

¹ Reference is made by Mr. Aaronsohn to the so-called *Triticum aegilopoides*, a natural hybrid found in the vicinity of Montpellier, France, as described by Fabre, Godron, Jordan, and others. See also Bally, W., *Chromosomenzahlen bei Triticum- und Aegilopsarten, ein cytologischer Beitrag zum Weizenproblem*, *Berichte der Deutschen Botanischen Gesellschaft*, v. 30, p. 163, 1912.

this spikelet were waiting for fertilization. Other young heads of the same plant did not show any spreading glumes, but it was found that some of the younger heads would spread their glumes as soon as the plants were pulled up. The change of position required only a moment, so that it was possible to see the glumes open.

The visible spreading and closing of the glumes when the plants were pulled left no doubt, of course, that these organs are capable of motion or that they can change their position promptly, to take advantage of special conditions. The plant is evidently possessed of a mechanism that causes the glumes of flowers of the right age to open, doubtless as a result of some particular condition of internal pressure or turgor. The favorable condition is very soon passed and the glumes are closed again. If the opened heads are dropped into alcohol they open still farther, but close up later on. Only in a few spikelets that were put under immediate pressure was it possible to secure any permanent illustration of the open position. (Fig. 2.)

The power of motion is evidently confined to glumes in certain stages of development. Very young heads containing small immature anthers did not open their glumes with other heads of the same plants, nor did older heads with grains that had grown to about half the adult length. But some of the heads that opened their glumes when the plants were pulled had undoubtedly passed the stage of fertilization. The glumes of the lower spikelets of a head would sometimes open when those of the upper spikelets did not, the lower being less advanced in development.

Though the power of motion evidently does not cease entirely at the time of fertilization, it is undoubtedly present during that period, and enables the plants to take advantage of brief periods of time when the conditions are most favorable for cross-pollination, doubtless depending on air temperature and humidity. These factors must be greatly influenced by exposure, in a region so broken as the wild-



FIG. 2.—Open spikelets of wild wheat, showing the position of the parts at the time of flowering. (Natural size.)

wheat country about Mount Hermon. As nearly as could be judged from limited opportunities of observation, the shedding of the pollen and the opening of glumes seem to occur within a short time, perhaps not more than half an hour after the plants have been exposed to the light and warmth of the morning sun; that is, the period of the drying of the dew, which is not heavy on the denuded slopes, where most of the wild wheat grows.¹

It has been observed by Mr. J. B. Norton, of the Bureau of Plant Industry, that the flowers of rye are sensitive to mechanical irritation and can be induced to open by slight rubbing with the hand. The same may be true of the wild wheat, and may account for the opening of the glumes on the plants that were pulled up. Under natural conditions a mechanical stimulus would be applied when the awns are shaken by the wind. A breeze that would bring pollen to the flowers might at the same time afford the stimulus for opening the flowers to receive the pollen. If the awns serve in this way as a part of the mechanism for opening the flowers another remarkable specialization must be added to the list of cross-fertilizing adaptations among the wild cereals.

ANALOGIES WITH DOMESTICATED WHEAT.

The specialized adaptations of the wild wheat should be taken into account in attempting to understand the status of domesticated varieties with reference to cross-fertilization. Whether the wild wheat of Palestine be considered as the prototype of the domesticated wheat or not, it is reasonable to look upon its habits as affording the best analogy with those of the ancestral form of the cultivated wheat. The condition of self-fertilization in the cultivated varieties involves the loss of some of the specialized features of the wild plant, such as the exertion of the anthers and the spreading of the glumes. The awns also seem to be quite without function in the self-fertilized varieties, many of which are awnless. That these characteristics should have disappeared equally from all of the very numerous cultivated sorts would not be expected and is not the case.

Some of the forms of cultivated wheat of Palestine still share the habit of cross-fertilization with the wild wheat. This was definitely indicated by the finding of heads of cultivated wheat with the glumes spread like those of wild wheat in the same district where the wild wheat grows, on the slopes of Mount Hermon, above Arny. It was near the upper limit of wheat cultivation, the only place where the

¹ Mr. Aaronsohn has observed that the dew is sometimes quite heavy, but that on such days the glumes remain closed, or open for only a very short period, probably because the air is already too dry and the temperature too high by the time the dew has evaporated. Near the coast the opening of the glumes takes place between 7 and 8 o'clock in the morning and from 5 to 5.30 in the afternoon.

cultivated wheat was seen in the flowering stage. A few days before several spontaneous plants of domesticated wheat had been seen near El Hadr with many exerted anthers. The plants that showed the open glumes were vigorous individuals, growing close to an irrigation ditch. Both plants belonged to the same general type, which may be considered as a primitive form of the domesticated species in view of the apparent retention of the habit of cross-fertilization. The glumes of the domesticated wheat were open early in the morning, as in the wild wheat.

In a recent report on the crossing of wheat in India the suggestion is made that cross-fertilization takes place when the glumes are opened by the wilting of the plants in the middle of the day.¹

ADAPTATIONS FOR DISSEMINATION AND GERMINATION.

STRUCTURE OF RACHIS AND SPIKELETS.

Though domesticated plants are superior to wild species from the standpoint of utility to man, this superiority often involves a loss of some of the specialized characters that were of use to the plants in the wild state. From a biological viewpoint the wild wheat appears superior to the domesticated plant in its adaptations for protection and sowing of the seed, as well as in its better provision for cross-fertilization.

In the discussion of cereals from the agricultural standpoint the difference between the heads of wheat and barley is usually described by saying that barley has a fragile or brittle rachis, but this expression seems inadequate to describe the fact for biological purposes. The rachis of the wild wheat as well as of wild barley is not merely brittle in the sense of being broken easily, but is provided with

¹ "It will be evident from the above that natural crossing in wheat is far more frequent under the conditions obtaining on the canal colonies of the Punjab than it is in Bihar. At Pusa five cases have been proved. Two hundred and thirty-one cases were proved by us at Lyallpur, and of these no less than 226 took place in 1907. In the dry climate of the Chenab colony, wheat is grown entirely by canal irrigation and is usually watered at least twice after sowing, the last watering taking place after the plants are in ear. Often before this last irrigation the supply of water in the soil is so small that the plants wilt during the hottest part of the day, the glumes open, and the stigmas are exposed to the air. Under such circumstances, in the dry, hot climate, natural crossing is easy and it is not surprising, therefore, that it is so frequent. Experimental cultures might be protected to some extent from natural crossing by more frequent and even watering. Wheat breeding will always be very difficult at Lyallpur, and it will be necessary to bag the F₁ generation at least. Pure line cultures will have to be rogued every year and frequently reselected, and the trouble and difficulty of growing pure seed for cultivators will be considerable.

"In the damper climate of North Bihar, where wheat is grown without irrigation on high-moisture-retaining loams, natural crossing although occurring gives little trouble in selection and breeding work.

"It will be evident that the environment may modify to a considerable extent the usual pollination mechanism in a crop. In northern Europe cross-pollination in wheat is a rare occurrence; in warmer climates it is more frequent; while in hot, dry localities, such as the canal colonies of the Punjab, where the crop can only be grown by means of artificial irrigation, cross-pollination is quite common." See Howard, A., Howard, Gabrielle L. C., and Khan, Abdur Rahman, "The economic significance of natural cross-fertilization in India," *Memoirs of the Department of Agriculture in India, botanical series*, vol. 3, no. 6, October, 1910, p. 302-303.

specialized articulations that separate of their own accord at maturity. Moreover, the joints are not only constructed to fall apart from each other at maturity, but to remain firmly attached to the spikelet. The joint becomes, in effect, the beak of a spikelet, rendering that organ much more efficient for carrying the seed and burying it in the ground.

The utility of the joints of the rachis as beaks for the spikelets is greatly increased by the fact that they are barbed along the edges and at the upper end with long, stiff bristles. Thus, with respect to the rachis, there appear to be two distinct differences between the wild wheat and the domesticated. The wild wheat has the rachis jointed, with the spikelets firmly fastened to the joints, while the domesticated wheat has the rachis entire and the spikelets jointed to the rachis.

The jointed rachis is not the only difference in the structure of the head of the wild wheat. Instead of dropping apart and allowing the grains to fall out at maturity, the spikelets of the wild wheat function as useful organs for disseminating and planting the seeds. The glumes are very hard and tough and are grown fast to the joints of the rachis. Instead of being readily broken off and separated from each other to liberate the kernels, as in the domesticated wheat, the kernels of the wild wheat are not normally released from the spikelet. A simple rubbing in the hand is sufficient to separate the glumes and kernels of the domesticated wheat from each other and from the rachis, but much more persistent rubbing leaves the spikelets of the wild wheat still intact. Indeed, it is very doubtful whether the wild wheat could be thrashed with any ordinary machinery, so compact and tough are the spikelets.

THE SPIKELETS AS BURROWING ORGANS.

The highly specialized nature of these joints of the rachis may also be judged by the fact that the articulation is not at the end, but on one side. The effect of this adaptation is to leave the end of the beak nicely smoothed and rounded, well suited for slipping along over ordinary surfaces, not pointed enough to enter or be impeded by minute apertures or roughness, but well suited to creep into larger crevices under stones and clods or to burrow into loose earth.

In an open space without obstructions the spikelets could be blown long distances or they could be lifted by whirlwinds, which must be effective agents of dissemination of plants in desert regions. But even under ordinary conditions, in the presence of many plants and the surface inequalities of rocky soils, the wild-wheat spikelets are probably able to creep along for several feet. This was indicated by the many cases in which numerous spikelets were found crowded

under the same stone or deeply buried in the same little mound of loose earth thrown up by moles or burrowing rodents.

The spikelets evidently do not cease their movements as soon as shelter is found, but often continue to burrow until only an inch or less of the ends of the beards remains exposed. Further appreciation of the burrowing mechanism is gained when an attempt is made to draw the spikelets out of their retreats. A strong pull is likely to be required unless the earth happens to be loose. Many attempts fail because the tough beards often break off, leaving the buried spikelets behind. That the spikelets can be so deeply buried by the action of the wind alone is hard to believe. Hygroscopic movements are possible, such as the twisting and untwisting of the beards by daily changes of humidity.

RELATION OF DISSEMINATION TO CROSSING.

Specializations that assist in the dissemination of seeds serve not only to extend the geographical distribution of the species, but probably have a still more important physiological function in facilitating cross-fertilization. If the seeds have means of being carried about, the plants of the next generation are much less likely to have close relatives as neighbors. A wider range of cross-fertilization is secured, which contributes to the vigor and fertility of the species.

From this point of view it is possible to appreciate another reason for the evident tendency to reduce the wild-wheat spikelets to a single fertile seed. The development of two seeds from the same spikelet may involve not only an undesirable competition between the two plants but a mutual injury from consanguineous pollen. Thus, it is possible to understand how the development of an indehiscent spikelet for the better protection, dissemination, and planting of the seeds would establish in turn a condition of natural selection in favor of the reduction of the spikelet to a single fertile seed.

INEQUALITY OF SEEDS.

The extent to which spikelets of the wild wheat represent specialized organs for planting the seeds may also be judged from another curious fact shown in an experimental planting of the wild wheat at San Antonio, Tex., in the spring of 1911. Although two seeds are present in most of the spikelets, it is unusual for more than one of them to germinate. Out of 175 spikelets dug up at San Antonio only 6 showed the development of two seedlings from the same spikelet. A detailed examination showed 31 single-seeded spikelets, leaving a remainder of 138 with two seeds in each spikelet, only one of

which germinated. The two seedlings that were produced from the same spikelets in the six cases were approximately equal in size, and like those from the other spikelets, they were already several inches tall. None of the second seeds in the other spikelets showed any sign of germination. In a few instances decay had set in, but most of the seeds were still intact. The endosperm was softened to a pasty consistency, though still pure white. This seemed to exclude the possibility that failure to germinate had been due to lack of moisture.

An examination of a sample from the same stock of imported seed from El Hadr, Palestine, showed 144 spikelets with two seeds to 93 with one seed. The large and small kernels were sorted apart as the spikelets were opened and weighed separately. The average weight of the 144 large kernels was 0.027 gram, while the small kernels weighed only 0.018 gram. The 93 kernels from the single-seeded spikelets gave an average of 0.022 gram, which figure also represented the general average for the total number of 381 kernels.

The nature of this specialization is not yet apparent. At least three possibilities have to be considered. One of the seeds may be imperfect and unable to germinate or the germination of one seed may in some unknown manner prevent the germination of the other. Again, the seeds may be unlike, so as to germinate at different times, in some such way as in *Atriplex* and *Xanthium*. Some of these possibilities are easily tested, but others may require some time.

Whatever the nature of the specialization, its advantage is plain. It is easy to understand that in dry regions like those where the wild wheat is native the germination of a single seed is much more likely to be accomplished safely than that of two seeds. And even after germination the chances of reaching a productive maturity would be much greater for one plant standing alone than for two plants standing close together and competing for the scanty moisture of the soil.

POSITIONAL RELATIONS OF SEEDS AND GLUMES.

When the awns are distinctly unequal, as they usually are, it is always the basal flower that has the larger awn and the second flower that has the smaller. The smaller awn always accompanies the glume that projects the most at base, unless it is very much reduced. On the other hand, it is the basal flower that has the smaller grain.

The possibility that the inequalities of the awns and seeds might have some relation to their position on the head was considered, but no consistent differences were noticed. As the heads stand in oblique positions, the spikelets are not regularly arranged to have the large awn above or below, nor is there any regular alternation. On some heads several spikelets that show the same position of the

large and small awns may be found on the same side, followed by an abrupt change to the other kind of spikelet.

If the spikelets are laid down in the same position, some will appear to be right handed and others left handed, with reference to the large awns. This relation is determined by their position in the spikelet, but seems to have no regular relation to the position of the spikelet on the head. It seems to be entirely a matter of chance whether a spikelet is to be right handed or left handed. This is indicated by equality in the numbers of right-handed and left-handed spikelets. A count of 224 spikelets showed 112 right handed and 112 left handed.

The presence of more heavy grains on one side may affect the position of the heads, which often stand in inclined or oblique positions with the broad sides of the heads facing upward and downward. In the usual positions of the heads of the wild wheat the rachis stands on edge, which is at right angles with the position of inclined heads of domesticated wheat where the rachis lies on its side, with one row of spikelets above and the other below.

RELATIONSHIPS OF THE WILD WHEAT.

The relationships of the wild wheat are of practical interest from the standpoint of breeding, quite apart from the question of a direct utilization of the plant. In the investigation of breeding problems, there is a distinct advantage in having two or more allied plants to serve as a basis for comparison. Many variations and differences of behavior that would otherwise escape notice are likely to be brought out by comparison. Even the most familiar facts may fail of proper appreciation until they are thrown into contrast by comparison with different characters or conditions. Though the comparative methods have been generally recognized as the chief basis of modern biological science, the application of such methods is frequently neglected in dealing with practical problems. In attempting to determine the direct economic value of a plant it is easy to overlook the indirect economic value that it may have in throwing light upon the behavior of another species.

HISTORICAL INTEREST OF THE WILD PROTOTYPE.

In addition to the interest of the wild wheat from the breeding standpoint is its historical interest as a possible prototype of the most important of cereals. To locate the original home and place of domestication of the wheat plant is also to locate a probable center or starting point of ancient civilization.

This preeminent interest of the wheat plant may be questioned, perhaps, on the ground that the rice plant of tropical Asia or the maize

plant of tropical America sustains more millions of people or represents a more ancient domestication than the wheat plant. Yet the wheat was at least the chief basis of the ancient civilization of the Mediterranean region, as well as of the modern civilization of northern Europe, to say nothing of the Asiatic countries where wheat was grown in ancient times or of the more remote regions in America and Australia that have been occupied in recent centuries by wheat-growing European populations.

That Palestine has a wild wheat plant, with all the characters predicted for the unknown prototype by the most eminent European specialists, Mr. Aaronsohn has certainly demonstrated, but a number of problems remain to be solved by further explorations and experiments before the prototype question can be said to have had an adequate scientific treatment. Some of these inquiries are already receiving Mr. Aaronsohn's attention, and additional evidence may be expected at any time.

THE JOINTED RACHIS A PRIMITIVE CHARACTER.

The jointed rachis, which has been so largely relied upon as a distinguishing feature of a true prototype, is hardly to be considered sufficient ground for a final determination. That some more or less remote ancestor of the domesticated wheat had a jointed rachis is not an unreasonable assumption in view of the agreement in this respect among many wild species of several related genera of grasses—*Triticum*, *Hordeum*, *Agropyron*, *Aegilops*, etc. Even the presence of long beards in domesticated wheats may be used as an indication of an originally jointed rachis, since it is only in connection with such a rachis that beards appear to have a definite function in planting the spikelet. But these deductions throw no light on the question whether the function was lost before domestication took place or afterwards. The beard and rachis characters are present in many wild grasses and absent in many others.

Something may be learned regarding the rachis characters by the study of hybrids, some of which have been already made in Germany by the younger Koernicke and in Palestine by Mr. Aaronsohn. It may be that the analogy of hybrids between wild and domesticated types of barley, studied by Koernicke and Tschermak, will also apply to wheat. These investigators found that the brittle rachis of the wild barley did not behave as a dominant character, but disappeared in the hybrids. This is also true of the supposed natural hybrid between the wild wheat and *Aegilops ovata*. The three spikelets that formed at least the upper part of the head are firmly joined together, as in *Aegilops*, instead of being the first to fall apart, as in the wild wheat.

The analogy in some of the characters seems very close between the wild wheat and the emmers, but even though the wild wheat be accepted as the prototype of the emmers there is still a question as to whether the emmers came from the same original domestication as did the true wheats. In view of the rich diversity of forms in the genus *Triticum* and its relatives there is nothing unreasonable in the idea that several wild species were domesticated, as most botanists seem to have concluded in proposing and accepting the current classifications.

The general occurrence of wild wheat with wild barley has suggested to Mr. Aaronsohn the probability that the two might have been domesticated together. But if cereals as diverse as wheat and barley were not distinguished by primitive man there is less reason to believe that a separation would be made between the different kinds of wheat or between wheat, spelt, and emmer. The same general tendencies of unconscious selection, to suppress the jointed rachis and the cross-fertilizing adaptations, are apparent in barley and oats, as well as in the different kinds of wheat. Even if the different forms of *Triticum* did not grow in the same localities originally, such mixtures might easily be made with the extension of cultivation into other regions, just as the corn cockle, chess, and other weeds have been spread with wheat. For primitive peoples a mixture of several cereals might be better than a pure stock, for the crop might be safer, even if less abundant. The custom of planting mixed grains seems to have continued in Europe nearly to the present day. The combination of wheat and rye even had a special name in English and in French, "meslin" and "métel," respectively.¹

POSSIBLE EXISTENCE OF OTHER PROTOTYPES.

The botanical evidence may be sufficient to show that the jointed rachis is a primitive character for a large group of species, but this affords no assurance that any particular species with the jointed rachis was the long-sought prototype of wheat. That so common and even so conspicuous a grass as wild wheat should remain so long overlooked in a country that has received as much botanical attention as Palestine, makes it entirely conceivable, to say the least, that other wild species of *Triticum* may exist in the Arabian Peninsula or

¹ "Meslin, or métal.—The French have a custom of cultivating what they call métal, but what is called, in English, meslin; that is, a mixture of wheat and rye. The proportions are not very exactly determined. If the land is more favorable to wheat than rye, more of wheat is sown in the mixture than of rye, and the contrary. It yields a good crop when sown after wheat, when wheat following wheat would not be advisable. This culture is far from being universally approved in France; but some eminent farmers maintain that the crop is more sure than any other, that it is not easily lodged, and that neither the rye nor the wheat is so liable to rust or mildew as when cultivated alone. It sometimes happens, likewise, that the season is not favorable to one of the kinds of grain when the other yields a crop. It follows potatoes to advantage. It is generally consumed on the farm in preference to being sent to market, and it makes a healthy bread." (Colman, Henry, "The Agriculture and Rural Economy of France, Belgium, Holland, and Switzerland," 1848, p. 103.)

in the other vast regions of western and central Asia, which have not received a tithe of the botanical attention given to Palestine.

And even though no other wild types of wheat should be discovered by further exploration, there is another interesting possibility in more definitely fixing the status of the domesticated type of wheat, which grows so frequently as a spontaneous plant. That it is not a wild plant in Palestine, at least in any such sense as the wild wheat, is very apparent in the districts where the wild wheat grows, and may be true of all the adjacent regions, as Mr. Aaronsohn's observations have led him to conclude, but if the domesticated type of wheat could be found to behave as a wild plant in Arabia or elsewhere in western Asia there might be no necessity of looking to any different plant as a prototype.

As pointed out by Mr. Aaronsohn, the wild wheat seems to be rather strictly confined to the calcareous soils in the region of Mount Hermon, and is often completely absent from the small areas of volcanic soils that in many places interrupt the limestone formations. Whether this apparent preference for limestone has reference to chemical or to physical factors is not yet known. The volcanic soils, though often very fertile, may remain too dry at the surface to permit the germination of the seedlings. On the other hand, the spontaneous or escaped form of domesticated wheat often seemed to prefer volcanic soils. This was noticed especially in the vicinity of El Hadr, where the spontaneous wheat was sometimes abundant, even in places that did not seem to have had any recent cultivation, though the seeds may have been dropped from the harvests of neighboring fields.

TRITICUM MONOCOCCUM EXCLUDED AS PROTOTYPE.

That another wild wheat should exist in the same region, though in a different geological formation, would not be an argument against the possibility that the spontaneous wheat of the volcanic soils might represent the ancestral form of the domesticated type. Indeed, the Palestine country affords three spontaneous types of *Triticum*, for Mr. Aaronsohn has found a wild form of *T. monococcum*, only very slightly different from the cultivated einkorn. This species is not known to be cultivated in Palestine or adjacent regions, though still grown to a slight extent in Europe. At the time of Schliemann's excavations of the site of ancient Troy it was reported that the einkorn wheat had been found, which suggested the idea that the einkorn might represent the primitive form of cultivated wheat, but Mr. Aaronsohn states that Wittmack afterwards identified the specimens as barley, on the basis of a microscopical examination. Another reason for excluding *T. monococcum* from consideration as a possible

prototype of domesticated wheat is the fact that it has not been found to produce fertile hybrids with the other cultivated species of *Triticum*.

Spelt also has been looked upon as a primitive type of wheat, but it seems not to have been mentioned before the time of the Emperor Diocletian. Thus, by a process of exclusion it has been argued that emmer (*Triticum dicoccum*) must represent the most primitive type, so that Mr. Aaronsohn's wild emmerlike plant certainly leaves nothing to be desired from the standpoint of the theories of the German specialists. On the basis of the existing knowledge of the plants and their habits the only other alternative that seems worthy of consideration is the possibility that the cultivated wheat represents its own wild prototype more nearly than the other plants that have been proposed as ancestors.

SPONTANEOUS FORMS OF DOMESTICATED WHEAT.

In other words it is a choice between the wild wheat of Palestine and the plant that has been looked upon as an escaped or spontaneous form of the domesticated wheat. Acceptance of the latter alternative would bring the wheat plant directly into line with what is known regarding the wild types of other agricultural plants of Old World origin. It seems to be a general fact that the domesticated plants of the Old World are still very closely similar to their wild ancestors, whereas in America several of the most important domesticated plants, such as Indian corn, coconuts, cassava, and peanuts have not been found to represent any wild species now in existence.

So far as the jointed rachis bears on the question it does not seem any less reasonable to consider the possibility of finding a wild wheat without a continuous rachis or less specialized joints than to believe in the development of the domesticated type of wheat from a plant with the rachis so highly specialized as the wild wheat of Palestine.

COMPARISON OF WILD WHEAT WITH AEGILOPS.

As an example of the suppression of the joints of the rachis in a wild relative of wheat, mention may be made of *Aegilops ovata*, a plant very common in the wild-wheat country of Palestine, formerly considered as the prototype of wheat by De Candolle and others. In this species of *Aegilops*, specialization has taken the direction of uniting some of the joints of the rachis, so that the whole head functions together as an organ of dissemination. The head is articulated only at the base, below the fertile spikelets, of which there are usually two. The second fertile spikelet is permanently attached to the first, as well as the reduced sterile spikelets that form a stiff brush of bristles. The suppression of articulations in this wild plant makes

it unnecessary to suppose that the continuous rachis of the domesticated wheat has been derived in domestication, or that the jointed rachis is a necessary character for all wild types.

If the wild prototype of the wheat had a jointed rachis, it is strange that reversions to this condition should not occur, at least in small depauperate forms of the domesticated species; yet no such tendency was noted in any of the spontaneous wheat in Palestine.

ORDER OF MATURITY OF SPIKELETS.

According to Mr. Aaronsohn's observations, the order of maturity of the spikelets on heads of domesticated wheat is not the same as on the wild wheat. As might be expected from the earlier maturity of the seed, the terminal spikelets of the wild wheat are the first to develop their flowers, whereas in the domesticated type the spikelets near the middle of the head are the first to mature. While such a change of the sequence of maturity of the flowers appears much less serious than the modifications that must be assumed to have taken place in the structure of the rachis, the fact can hardly be considered as an evidence of close relationship. There is no apparent reason why a loss of the structural specialization of the rachis should have involved a change in the order of the development of the flowers.

Another feature in which the wild wheat seems more specialized than the domesticated type is the greater reduction of the middle or infertile flower of the spikelet. In some varieties of wheat the spikelets have several fertile flowers. A single smutted head of domesticated wheat found at El Hadr had an increased number of seeds in the spikelets.

SEEDLING CHARACTERS OF WILD WHEAT.

Although the spikelets of *Aegilops* are very different from those of *Triticum*, Ascherson has united the genera because *Aegilops ovata* has been found to hybridize readily with wheats and has three radicles instead of one, as in other species of *Aegilops*. *Triticum* has three radicles and *Secale* four.

Germinating seedlings of the wild wheat are not absolutely regular in the number of radicles; most of them put forth three, though in some cases there are only two, and occasionally four or five. A count of the radicles of some seedlings of wild wheat germinated at San Antonio, Tex., in April, 1911, showed 162 with three radicles, 12 with two radicles, 4 with four radicles, and 2 with five radicles.

Unlike the wild barley, the radicles of the wild wheat emerge from both faces of the spikelet. In the barley the whole group of five or six radicles breaks through the outer face of the spikelet. The

scutellum of barley lies parallel to the outer face of the spikelet, while that of the wheat lies across the spikelet. Though the emergence of the radicles of the wild wheat from both faces of the spikelet is a constant feature, there is no apparent regularity in their distribution. Of 150 spikelets where this point was noted, two of the radicles came from the outer rounded face of the spikelet in 80 cases, while two came from the inner face in 70 cases.

WILD WHEAT AND WILD BARLEY.

It is not easy to believe that a plant so highly specialized as the wild wheat of Palestine should have lost so many of its peculiarities as the cultivated types must be supposed to have done, if the wild wheat is to be accepted as the true prototype. The domesticated barley seems much closer to the wild species than in the case of the wheat, not only in the structure of the rachis, but in that of the spikelet as well. The 6-rowed barleys represent the loss of one of the specializations of the wild type, the reduction to a single fertile spikelet, but the 2-rowed types of barley offer very close and very general analogy with the wild plant. Some writers have held that the 6-rowed barley must have been derived from a different wild species. Some of the wild species of *Hordeum* in Palestine have the seeds arranged in 6 rows, with a superficial resemblance to the 6-rowed barley.¹ The loss of the jointed rachis in the domesticated barley renders the beards as useless, as organs of dissemination, as those of the domesticated wheat. Nature abounds in examples of apparently useless characters, but it is difficult to believe that so specialized an organ would have developed unless it had adaptive value for the wild ancestral type.

SELECTIVE ELIMINATION OF CROSS-FERTILIZATION.

The cross-fertilizing adaptations in the wild wheat do not constitute an objection to its being considered as the true prototype. Not only are such adaptations shared to some extent by the domesticated species, but the conditions of domestication involve an important factor of unconscious selection toward the habit of self-fertilization. With the wheat growing as a wild plant under ideal weather conditions, like those found on the slopes of Mount Hermon in May and June, natural crossing is on the same footing as in other wild plants of similar habits.

As soon as such a plant began to be grown as a cultivated crop and extended to more extreme conditions, unconscious selection

¹ Mr. Aaronsohn states that he has crossed the 2-rowed wild barley (*Hordeum spontaneum*) with domesticated 4-rowed barley and that a considerable number of 6-rowed ears appeared in the first generation, though most of the ears were of the 4-rowed form.

would favor self-fertilization. In proportion as the weather is too dry or too wet or too cold for cross-fertilization at the time of flowering, the resulting crop is limited to the lines of descent that have the habit of self-fertilization. The exertion of the anthers and the opening of the glumes would be ineffective or even injurious in bad weather. Lines of descent dependent upon cross-fertilization would be eliminated. Eventually only those lines would remain that brought the stamens and stigmas to maturity at the same time. All tendencies toward dimorphic conditions of proterandry or proterogyny would be forbidden by unconscious selection. The same result has been reached in some of the carefully bred varieties of corn, though all of the more primitive types show a pronounced condition of proterandry.

CONDITIONS OF DOMESTICATION OF WILD WHEAT.

DIFFICULTIES OF PRIMARY DOMESTICATION.

Another point of view from which the prototype question may be approached is that of domestication. Is such a plant as the wild wheat likely to have been domesticated by primitive man or is it more reasonable to believe that the true prototype must have been better suited to domestication? Or it may be asked whether the domestication of such a plant as the wild wheat could have represented a new or independent beginning of the art of agriculture. The alternative possibility is that instead of such a direct or primary domestication there may have been an indirect or secondary domestication by a people with agricultural habits already established.

Considering the plant alone, apart from any historical prepossessions, it must be admitted that the jointed rachis, long beards, and tough, close-fitting glumes would render the wild wheat a rather unpromising subject for domestication at the hands of a very primitive people. The seed is hard to collect and hard to separate from the chaff. Though the plants grow abundantly in some localities, the difficulties of collecting the grain and separating it from the chaff would stand in the way of its becoming the sustenance of a very primitive nonagricultural people or of serving as the basis of an original development of the art of agriculture.

Without an equipment of baskets or bags for gathering the separate spikes or a habit of using mortars or other means of beating out and winnowing the grains, the utilization of such a plant would seem well-nigh impossible. The traditional method of cutting or pulling the heads of wheat and binding them into bundles could not be applied at all to the wild wheat because of the jointed rachis, which allows the spikelets to fall apart as soon as they are mature. Ordi-

nary treading or thrashing would be quite ineffective for separating the wild-wheat grains from the chaff of the firmly closed spikelets. With the beards and bristles burned off and the chaff made brittle by exposure to fire and then beaten in a mortar, a separation of the grains could probably be accomplished.

Attention has been called by Mr. F. H. Chittenden, of the Bureau of Entomology, to the unusual hardness of the grains of the wild wheat as likely to give it protection against insect injury in storage, though in a few cases the husks of the imported seed showed signs of attack by the Angoumois grain moth (*Sitotroga cerealella*), a well-known cosmopolitan insect which preys upon practically all cereals. The hardness of the grains would not interfere with domestication by a people accustomed to soften their food by soaking, grinding, or cooking, but would offer some difficulties under the theory that primitive man began by eating raw cereals.

SECONDARY DOMESTICATION MORE PROBABLE.

When the wild wheat is able to invade cultivated land it grows much more vigorously and forms larger and more numerous heads in a way that would be much more likely to secure the attention of a primitive people. It is conceivable that an agricultural tribe settled in a neighborhood where the wild wheat grew might gather the grain in times of scarcity and finally adopt the plant into cultivation. It is possible that the plant grew wild in former times in the more favorable places that are now under regular cultivation. But any considerable extension of this kind may be doubted, in view of the probability that permanent vegetation of shrubs and trees formerly occupied all except the most rocky and barren lands, where the plant still seems to find its most congenial home. Instead of agriculture having restricted the distribution of the wild wheat, the denudation of a country like Palestine is much more likely to increase the distribution of the desert types, which gradually replace those that require fertile or moist soils.

Assuming that the wild wheat is the true prototype of our cultivated wheats, it would seem most reasonable to believe that the domesticators of such a plant were already an agricultural people accustomed to the use of other seed plants for food and equipped with some primitive means of gathering and thrashing, as well as of grinding and cooking. In Mexico and other parts of tropical America wild seeds are often gathered by agricultural Indians to supplement corn or other crops. Among the California Indians the arts of gathering, winnowing, and grinding wild seeds were highly developed. This was true even in tribes that had no agriculture at all, though such habits might have been borrowed from the agricultural tribes

in the southern part of the State. Moreover, the California seed-eating Indians had settled habitations or, at least, were confined to limited districts, instead of being pastoral nomads, as the early inhabitants of Palestine are supposed to have been.

BORROWING OF DOMESTICATED ANIMALS AND PLANTS.

The treatment of wheat and other small grains as secondary domestications is in line with the probabilities regarding the domestication of animals. Instead of taking it for granted that the pastoral state was antecedent to agriculture, it should be recognized that settled agricultural tribes are much more likely to domesticate animals than are wandering savages, who live by hunting or fishing. The domestication of many species of animals in the Old World also presupposes the existence of a settled agricultural population. After animals have been domesticated they may be adopted by wandering hunting tribes that come into contact with more advanced agricultural peoples.

Many of our western hunting Indians, who long ago adopted horses and other domestic animals from the white man, still have very little interest in agricultural plants. But among the Indians of tropical America, where agriculture appears to have originated, many plants were found in cultivation by people who had no domestic animals at all or only household kinds, like parrots, guinea pigs, and dogs. With the exception of the llama of the mountains of Peru, no large grazing animals seem to have been domesticated in ancient America. There was nothing to compare to the horses, asses, camels, elephants, cattle, buffaloes, goats, sheep, pigs, etc., that were domesticated by the agricultural populations of the Eastern Hemisphere. Yet it is not to be imagined that the domestication of animals in the Old World preceded the domestication of plants any more than in America. Though the adoption of domestic animals may represent the first stage in the borrowing of an agricultural civilization, the original taming and domestication of an animal implies a settled existence and an adequate supply of food for the men themselves as well as for the animals; in other words, an agricultural status.

CIVILIZATION NOT INDIGENOUS IN EGYPT OR MESOPOTAMIA.

Modern archæological discoveries in Egypt and Mesopotamia tend to discredit the traditional idea that those regions were the scene of the first development of agriculture. The earliest civilizations in both countries are now ascribed to foreign populations that came in from the Indian Ocean or southern Arabia to Mesopotamia by way of the Persian Gulf and to Upper Egypt from the Red Sea. It was

formerly supposed that civilization was established earlier in the delta region of Egypt because of its proximity to Asia, the traditional home of the human race. It is now known that the civilization of Upper Egypt was more ancient than that of Lower Egypt and that the conquering race that established the historical dynasties came in from the East. Similarities are still recognized between the early stages of civilization in Egypt and those of the Chaldeans and Sumerians at the head of the Persian Gulf, but the present tendency is to explain these primitive approximations by community of origin from southern Arabia rather than by subsequent borrowing.

Notwithstanding the great antiquity of Egyptian civilization, it does not appear that the natural conditions in that country could have been very favorable for a first beginning of the art of agriculture. According to Herodotus the Egyptians had traditions of a time when all of the lower part of Egypt was a mere swamp, unfit for human habitation. The country must have been originally a flood plain of the Nile, with the native vegetation limited to plants that could endure the annual alternations of deep flood and prolonged drought, conditions that must have been unfavorable to the existence of wheat or other cultivated plants in a wild state. The native flora of Egypt may have been something like that of the flood plains of our southwestern rivers. The common Egyptian acacia recalls the screw bean and mesquite of the lower valley of the Colorado River in Arizona and California, a region capable, like Egypt, of supporting a large civilized population, but occupied hitherto by only a few scattering communities of very primitive Indians. Though it is now known that there was a native prehistoric population in Egypt before the dynastic invaders arrived, it is not certain that the native race occupied the actual flood plain of the Nile Valley to any such extent as in later and more civilized times. The stone implements and other characteristic remains of the primitive people have been found chiefly along the borders of the desert and in the Fayum and other oases rather than in the flood plain or Nile Valley proper.

ANTIQUITY OF AGRICULTURE IN AMERICA.

The tracing of the Egyptian and Chaldean civilizations, supposedly the most ancient, to southern Arabia has naturally suggested the possibility of a relation between the primitive civilization of Arabia and that of the shores of the Indian and Pacific Oceans. The same primitive system of tropical agriculture, accompanied by the same Polynesian type of language, extends all the way from Madagascar across the Malay region and all the inhabited islands of the Pacific Ocean. Moreover, the coconut palm and several other domesticated plants widely distributed in the Old World Tropics in

prehistoric times appear to have been of American origin, which would indicate that there was a Trans-Pacific communication of agricultural plants in early prehistoric times. That the agriculture of tropical America is more ancient than that of Asia or Africa is also indicated by the fact that the plants domesticated in the Eastern Hemisphere are still very similar to their wild relatives, whereas it has been very difficult to settle upon the wild types of many of the agricultural plants of America.¹

Though all the natives of America are considered by ethnologists as belonging to one general racial type, the local specializations of physical features, language, agriculture, and other arts and customs are such as to indicate a slow and gradual development through a very long period of time. The recent archæological discoveries in Egypt and Mesopotamia indicate that agricultural civilization may have existed in the Old World for 10,000 or 20,000 years. The archæological evidence regarding the antiquity of civilization in America is less direct, but from ethnological, biological, and agricultural considerations it seems not unreasonable to believe that the development of agriculture in America covers a much longer period than in the Old World, perhaps five or ten times as long.²

DIVERSITY IN WILD AND DOMESTICATED WHEATS.

INDIVIDUAL AND LOCAL DIFFERENCES IN WILD WHEAT.

Attention has been called in Mr. Aaronsohn's bulletin to the wide range of variation shown by the wild wheat. As such variations promised to be of interest from the standpoint of acclimatization it was intended to give them special attention in the field, in order to learn whether they represented local varieties or subspecies or only the normal individual diversity (heterism) of wild species. The heads of individual plants were to be collected separately as material for subsequent study and illustration of the facts of diversity.

It was soon found that the habits of the plants stood seriously in the way of securing definite results by this method. Plants that grew in uncultivated land generally produced only one or two heads and these often small, so that only a few seeds could be obtained from such individuals. Plants that had found more favorable conditions in cultivated fields often produced 10 or 15 heads as a result of abundant stooling, but it was seldom possible to determine with certainty that the whole cluster had come from a single original seed.

¹ Cook, O. F. Food plants of ancient America. Annual Report, Smithsonian Institution, 1903, p. 481-497. See also "History of the coconut palm in America," Contributions from the U. S. National Herbarium, vol. 14, p. 271, 1910.

² Cook, O. F. Vegetation affected by agriculture in Central America. Bulletin 145, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

In order to be certain that all of the heads from such clusters represented the same individual plant it would be necessary to locate and mark the individuals in the early stages of growth, before stooling began, or, better yet, to raise the plants from seed under experimental conditions. In view of these limitations it seemed best to spend the short time available in more general observations of the habits and characters of the plants and leave the more detailed study of the individual differences until some better opportunity could be secured.

Regarding the general question of the nature of the differences it became obvious enough that at least three factors or forms of diversity, which may be described as environmental, individual, and local, had to be taken into account. In addition to the differences of behavior that could be ascribed to inequalities of soil, moisture, or temperature, many individual differences of color, hairiness, pruinescence, and other details were always to be found among the plants of each locality where such comparisons were made. Perhaps the most obvious structural differences are those resulting from the varying development of the teeth at the outer angles of the glumes. A series of eight pairs of glumes taken at random from a stock of imported seed of the wild wheat collected at El Hadr is shown in figure 3.



FIG. 3.—Glumes of wild wheat, showing variations in the teeth. (Natural size.)

There were also more general differences that served to characterize local forms or races. Thus, in a nummulitic limestone district between Rosh Pinar and Khan Jubb Yusef, all of the wild wheat seemed to have the outer glumes of the spikelets densely hairy, much more so than in any of the plants previously studied on the slopes and foothills of Mount Hermon. (See Pls. VIII and IX.) A few miles nearer the Lake of Gennesaret (Bahr Tabariyeh) another form of wild wheat appeared, with the glumes smooth, but of very large size. Spikelets with hairy glumes occurred also at the same place, but were not so strongly hairy as in the previous locality.

The individual diversities were much more apparent among the large, many-headed plants in cultivated land. This may be ascribed in part to the fact that the large plants give much better opportunities

for observation. The repetition of the same characteristic by several large heads of the same plant brings them much more effectively to the observer's attention than if they are shown in only one or two small heads.

CORRESPONDING DIFFERENCES IN DOMESTICATED WHEAT.

Equally apparent differences in the extent of individual diversity under different conditions was also noticed in the domesticated type of wheat. The spontaneous plants usually produced only a single small head and seemed to show only about the same amount of diversity as the wild wheat. The color differences appeared somewhat less pronounced in the spontaneous plants of the domesticated wheat, but in the arrangement of the spikelets on the heads and the amount of bloom on the surfaces the escaped wheat appeared to be somewhat more variable than the wild type. Even in different fields of cultivated wheat there seemed to be distinct differences in the extent of diversity among the plants. On the higher slopes of Mount Hermon and in other places where the conditions were unfavorable, so that the plants remained small, they seemed much more alike than in the more fertile fields that had produced well-grown plants. Indeed, Palestine can still boast of many magnificent wheat fields in spite of age-long cultivation; nor has any attempt at selective improvement shorn away the primitive diversity of the cultivated plant, which even exceeds that of the wild type.

The great differences in the shape of the heads are responsible, no doubt, for the more obvious diversity of the domesticated wheat. In addition to a full series of different forms of heads, clubbed and open, broad and narrow, square and flat, there is an equally complete range in color—white, black, and red. Some heads are beardless, some have short beards, and some very long. The surfaces of the glumes are smooth or velvety, pruinose or naked, and so on through the whole series of details that are used to distinguish selected types of wheat.

NATURE AND SIGNIFICANCE OF DIVERSITY.

From the standpoint of some theories of heredity these displays of diversity in both the wild and cultivated types of wheat could not be supposed to have any biological interest or practical significance. They would both be looked upon as ordinary examples of what might be found in the field of almost any careless farmer in the United States—a mixture of different varieties. (See Pl. X.) When the facts are more carefully considered, this interpretation proves inadequate. It is certainly unreasonable to believe that anybody has ever separated the wild wheat into uniform varieties and then mixed them together again, nor is such a theory more justified in connection with the cultivated wheat of Palestine.

The nature and extent of the diversity in the domesticated type of wheat in Palestine may be judged by reference to Plate XI, which represents a few casually selected ears from the same field. In one case, at El Hadr, an attempt was made to find additional ears of a deep red, compact-headed form that happened to attract attention.

Figure 4 shows six ears that were picked as possible representatives of the desired type. Comparison showed, however, that they differ among themselves almost as much as the rest. One of the heads has black beards and very long beardlike teeth on the outer glumes. One of the other heads is heavily pruinose, while in another the glumes are nearly smooth and distinctly lighter in color, etc. Closer approxi-



FIG. 4.—Heads of domesticated wheat from El Hadr, Palestine, selected to show similarity of form and color. (Natural size.)

mations of type could doubtless be found by more careful comparison in the field, but before such selection can be undertaken to the best advantage something should be known regarding the adaptive values of the different characters and combinations.

The supposition of a previous selection of the domesticated wheat appears the more improbable when applied to such primitive people as the Druse mountaineers, who are the wheat growers of the slopes of Mount Hermon. That higher civilizations existed in these regions in ancient times than at the present may be true, but there is nothing to indicate that the primitive farming population of the Druse Mountains ever carried the selection of wheat any farther than at present.

In this respect, at least, it is reasonable to suppose that present conditions have existed from immemorial times. Damascus, on the plain to the east of Mount Hermon, has the traditional distinction of being the oldest city in the world.¹

SELECTION OF UNIFORM TYPES A MODERN ART.

De Vries infers that pure races of cereals were known to the Romans and quotes some lines from Vergil's *Georgics* in proof of the assertion. The passage states that the largest ears must be selected every year if degeneration is to be avoided, but this seems very far from the idea of isolating pure races. If such a degree of agricultural advancement had been attained among the ancients it is strange that no more definite reflections of it should have survived in literature. Even among the Chinese, who practiced conscious selection for many centuries, the idea of separating pure races of annual-crop plants seems not to have developed. In modern Europe this idea appears to be only about a century old, even if dated back to Lagasca's suggestion to Le Couteur, though that seems to have contemplated the classification of a diverse stock into types rather than a separation of progenies of single individuals as parents of pure races.²

¹ The Druses are a hardy agricultural people, physically well favored, and industrious. Their religion is said to forbid the use of narcotics in any form, including tobacco. Even coffee is refused by some, though used by our entertainers at El Hadr, flavored with seeds of Moringa. The Druses are said to have traditions of an emigration from Yemen in the seventh century, but such traditions are likely to refer to a noted warrior or band of conquerors who settled in the country, and would not preclude the possibility that the present population is essentially indigenous. The people are certainly entirely distinct both in features and habits from the surrounding desert Arabs, as well as from the Jews.

² De Vries describes this event as though the idea of separating the components of a mixed stock were entirely new:

"The fact that our cultivated plants are commonly mixtures of different sorts has not always been known. The first to recognize it seems to have been the Spanish professor of botany, Mariano Lagasca, who published a number of Spanish papers dealing with useful plants and botanical subjects between 1810 and 1830, among them a catalogue of plants cultivated in the Madrid Botanical Garden. Once when he was on a visit to Col. Le Couteur on his farm in Jersey, one of the Channel Islands off the coast of France, in discussing the value of the fields of wheat, he pointed out to his host that they were not really pure and uniform, as was thought at that time, and suggested the idea that some of the constituents might form a larger part in the harvest than others. In a single field he succeeded in distinguishing no less than 23 varieties, all growing together. Col. Le Couteur took the hint and saved the seeds of a single plant of each supposed variety separately. These he cultivated and multiplied till he got large lots of each and could compare their value. From among them he then chose the variety producing the greatest amount of the finest, whitest, and most nutritious flour. This he eventually placed in the market under the name of 'Talavera de Bellevue.' It is a tall, white variety, with long and slender white heads, almost without awns, and with fine, white, pointed kernels. It was introduced into commerce about 1830 and is still one of the most generally cultivated French wheats. * * * Hallet, the celebrated English wheat breeder, tried in vain to improve the peculiar qualities of this valuable production of Le Couteur's." (De Vries, "Species and Varieties, Their Origin by Mutation," 1905, p. 96.)

The first instance of isolation of the progeny of a single plant reported by De Vries was that of the Scotch breeder Sheriff in 1819. De Vries states:

"In the spring of 1819 he observed quite accidentally in a field of the farm of that name [Mungoswell] a single plant which attracted his attention by a deeper green and by being more heavily headed out. Without going into further details, he at once chose this specimen as the starting point of a new race. He destroyed the surrounding plants so as to give it more space, applied manure to its roots, and tended it with special care. It yielded 63 heads and nearly 2,500 grains. All of these were sown the following fall, and likewise in the succeeding years the whole harvest was sown in separate lots. After two years of rapid multiplication it proved to be a good, new variety and was brought into commerce." (De Vries, "Species and Varieties, Their Origin by Mutation," p. 110.)

Neither the diversity of the wild wheat nor that of the stock cultivated by the primitive people of Mount Hermon is to be considered as a peculiar or unusual fact demanding any special explanation. Similar diversity is probably to be found among the wild relatives of all our cultivated plants, as well as in the unselected stocks that have been domesticated by primitive peoples.¹ The only reason why the condition of diversity should seem strange or unexpected arises from the current opinion that wheat is a normally uniform, self-fertilized plant. The diversity of the wheat is only such as might be expected from the analogy of any other cross-fertilized plant, wild or domesticated.

RELATION OF CROSS-FERTILIZATION TO DISEASE RESISTANCE.

In addition to the general biological interest of diversity and cross-fertilization in the wild cereals, as already pointed out, these facts may have practical value from the standpoint of disease resistance. If cross-fertilization represents the normal ancestral condition of the wheat plant it is worth while to consider the possibility that absence of cross-fertilization involves a decline of vital efficiency. Lessened resistance to disease is one of the most general symptoms of weakened vitality in vegetative varieties, and the same is probably true of those propagated by continued self-fertilization.²

The form of the wheat rust that occurs on the barberry is now being considered as the sexual phase of the fungus. It has been suggested by Mr. W. T. Swingle that the pest may gain increased virulence through occasional crossing in the barberry stage and that the elimination of barberries and related plants from wheat-growing regions might result in an eventual weakening of the fungus by excluding crossing altogether.³

In addition to this possibility of mitigating the ravages of wheat rust by preventing the sexual reproduction, or at least the cross-fertilization, of the parasite, it is worth while to consider the possibility of securing and acclimatizing less susceptible varieties of wheat from primitive cross-fertilized stocks, if such really exist in Palestine or the neighboring regions. As often happens, the study of a question of general scientific interest may lead to a fact of practical agricultural importance. In learning something of the habits of the wild wheat a suggestion is gained regarding the behavior of the cultivated types of wheat.

¹ Mr. Aaronsohn finds much less diversity in domesticated barley and a still smaller amount in wild barley.

² Cook, O. F. The superiority of line breeding over narrow breeding. Bulletin 146, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

³ Mr. Aaronsohn states that wheat rust is destructive in some years, though there is no Barberis in Palestine. Experiments to test the relation of the sexual phase of rust fungi to virulence have been reported by Freeman and Johnson in Bulletin 216 of the Bureau of Plant Industry p. 33-45. In two years 52 generations of uredospores were grown without any appreciable diminution of vigor.

It is now regretted that this possibility of securing disease-resistant varieties by acclimatizing the domesticated wheat of Palestine in the United States did not suggest itself until a day or two before leaving the neighborhood of Mount Hermon, where the most extensive diversity and other indications of cross-fertilization were observed. The



FIG. 5.—Head of a large-seeded variation of wild wheat. (Natural size.)

apparently complete absence of rust on the wild wheat finally suggested a comparison in this regard with the cultivated wheat and brought to light the fact that the domesticated wheat was also free from rust. Rust was looked for in all of the fields that were afterwards visited, but with the same negative result so far as that district was concerned. The next day, down in the Jordan Valley, a few rusted stalks were seen, and a week afterwards between the Jewish colonies of Hedera and Petach Tikwa, to the south of the Plain of Sharon, a little rust was found in wheat that seemed distinctly inferior to that of the Mount Hermon district. Most of the wheat of the lower altitudes was already harvested.

Of course, there may be other reasons for the absence of rust quite apart from any quality of resistance the native varieties of Palestine may possess. A small planting of wild wheat at San Antonio, Tex., in the spring of 1911, that was severely attacked by rust shows that the plant has no complete immunity. But whatever the reasons for the apparent resistance to the rust, they are likely to prove interesting in the United States, where the most serious damage from rust fungi seems to occur in the parts of the country where the climate is warm, like that of Palestine. Indeed, the

wild wheat has been found by Mr. Aaronsohn to extend along the desert mountains to the east of the Jordan Valley almost to the shores of the Dead Sea, a region that resembles the Salton Sink of California, not only in lying below the level of the sea, but also in its climate, physical features, and to a certain extent in its specialized

desert vegetation. Yet in Palestine neither the wild nor the domesticated wheat is excluded by these extreme conditions. A German company is engaged in shipping wheat in boats across the Dead Sea to be carried up to Jerusalem by donkeys or camels. European settlers are beginning to establish themselves about Jericho, in the region that visitors from California are likely to look upon as the Imperial Valley of Palestine.

RELATION OF DIVERSITY TO ACCLIMATIZATION AND ADAPTATION.

Diversity is quite as important a factor in acclimatization and adaptation as in the breeding of new varieties. Breeders often resort to the crossing of varieties as a means of arousing some of the latent diversity of characters that has been suppressed by selection, in order to secure materials for further selection. In dealing with a diverse type that has never been reduced to uniformity by selection it is not necessary to begin by crossing, for a wealth of normal variation is already at hand. As much diversity may be expected in characters that give adaptation to external conditions as in the forms and color of the heads and other external features that serve to distinguish varieties.

The facts of diversity and the indications of cross-fertilization in these primitive and apparently rust-free stocks of wheat lend them special interest from the standpoint of acclimatization. Experiments with such stocks should make it possible to ascertain the full range of their possibilities of adaptation to special conditions of climate and soil. Even though the primitive and very diverse stocks should appear inferior to the more uniform stocks that could be obtained from localities where a certain amount of separation of varietal types

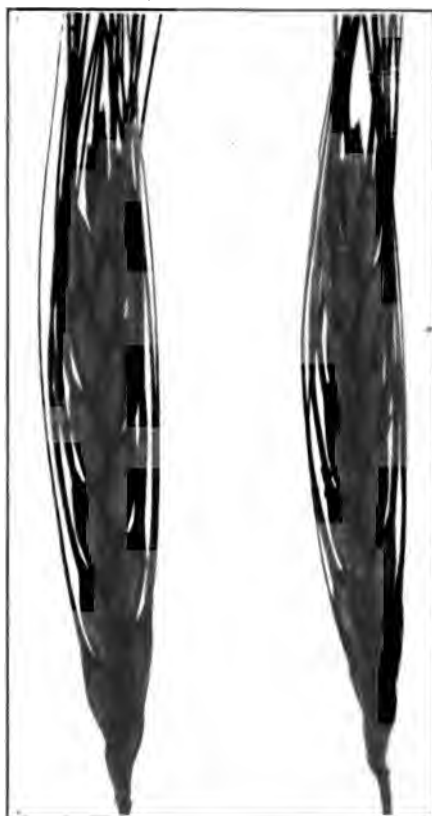


FIG. 6.—Nearly mature heads of wild wheat, ordinary form, to compare with figure 8. (Natural size.)

has taken place, experiments with the diverse stocks might still be worth while as giving a better opportunity to test the full range of adaptation to different local conditions in the United States.

The range of acclimatization and adaptation in carefully selected uniform varieties is often very narrow. The members of such a variety represent the expression of only one set of characters corresponding to the characters of a single individual in a normally diverse



FIG. 7.—Side view of heads of wild wheat of ordinary form, shown in figure 6, to compare with figure 9. (Natural size.)

stock. The function of selection is to regulate the expression of characters. Those lines of descent are preserved that bring the desired set of characters most uniformly into expression and keep latent all the undesirable characters. From the standpoint of the breeder any plant that shows a departure from the desired set of characters appears abnormal and is rogued out of the variety. To limit selected stocks as nearly as possible to the progeny of single individuals is the most effective method of preserving uniformity in the expression of characters. Thus a carefully selected variety may be said to have only an individual range of adaptation. As long as the variety is kept uniform its possibilities of adaptation are no greater than those of the original parent of the strain.

Diversity is likely to be aroused when a variety is transferred to new and unwonted conditions. Some of the reversions may prove better adapted to the new conditions than the parent variety, but there seem to be cases where little or no progress is made toward better adaptation. These artificial limitations are avoided when normally diverse stocks can be used instead of the chance variations of selected strains that may represent, after all, only a small part

of the adaptive possibilities of the species.

The use of the more diverse stocks for purposes of acclimatization also promises a great saving of labor and expense in conducting experiments. If the same or a greater range of possibilities of adaptation can be secured by plantings of a single diverse stock as from large numbers of selected varieties, much of the costly repetition of local tests of large numbers of varieties may be avoided. It is necessary

in most crops to isolate and make comparative tests of the most promising individual strains that become acclimatized, but this is vastly easier than to maintain separate plantings and selections of the large numbers of different stocks that are often brought together in variety tests.

SUPPRESSION OF ADAPTIVE CHARACTERS BY SELECTION.

Most of the careful selection that has been applied to wheat has been done in the different countries of northern Europe, in relatively cold, moist climates and with soil conditions unlike those of many of the wheat-growing regions of the United States. It is true that some useful importations have been made from Turkey and Russia, but even in such cases there could be no assurance that the selection that had been given to these varieties was calculated to secure the strains best adapted to our conditions. On the contrary, it is quite possible that the selection applied to



FIG. 8.—Nearly mature heads of a large-seeded variation of wild wheat, to compare with the ordinary form as shown in figure 6. (Natural size.)

the wheat plant in Europe, instead of improving it for our purposes, may have tended to suppress some of the characters that are needed to secure a full measure of adaptation in the United States. Characters that could be of the greatest importance in Kansas, Texas, or Arizona might be of no use in northern Europe and may have been suppressed by selection, even without any recognition of their existence. The strains that might be the best for our purposes may have been dropped out before the selected stocks reached the United States.

The extension of the wheat crop into northern climates may explain the suppression of cross-fertilization, as suggested in a previous

chapter. With rain or cold weather at the time of flowering only the self-fertilized plants might be able to secure pollination and set their seeds. While mere absence of the conditions of sunshine, heat, and dryness that may be required for the opening of the glumes or exsertion of anthers might not bring about a suppression of these characters, the repeated elimination of all of the plants that required cross-fertilization would constitute a very effective form of unconscious selection by unfavorable weather conditions. The tendency would be to place all the northern varieties on a basis of self-fertilization. Mr.



FIG. 9.—Side view of the heads of a large-seeded variation of wild wheat as shown in figure 8, to compare with figure 7. (Natural size.)

W. T. Swingle suggests the possibility that the greater vigor and disease resistance of the so-called durum wheats may be due to a retention of the habit of cross-fertilization, as well as to better adaptation to dry climates. If more vigorous individual strains resulted from occasional crossing they would gradually take the place of the others, especially if they proved more resistant to rust or other diseases. As yet there is no definite indication of how long a variety of wheat may be expected to maintain its vitality on a basis of strict self-fertilization. Even the idea of securing improved strains by isolation of the progenies of superior individual plants dates back only about a century, as already stated.

Though a cross-fertilized type of wheat might be valuable by reason of greater vigor, productiveness, or disease resistance, such a type would doubtless be more difficult to keep in uniform condition than a self-fertilized variety. Cross-fertilized varieties of wheat would probably require the same persistent attention that must be given to varieties of cotton and other cross-fertilized plants in order to establish and maintain a uniform expression of the characters. But even with the self-fertilized varieties continual reselection is needed to eliminate the degenerate individuals and lines of descent. This is shown by the favorable results that are nearly always reported from such experiments. The stronger the tendency to degeneration the more beneficial the effects of reselection will appear, for there are more of the inferior lines to eliminate.

The difficulty of securing uniformity of expression stands in the way of utilizing hybrids for the commercial culture of cotton, and the same factor is likely to be encountered with any open-fertilized wheat hybrids that might be produced. But there is no particular necessity that wheat kernels be exactly alike, if larger yields can be obtained from diverse cross-fertilized stocks. Millers often mix two kinds of wheat together to produce particular grades of flour. The importance of the crop is such as to warrant full investigation of any biological factors that seem to open the way of improvement. The factor of diversity enlarges the possibilities of adaptation to a wider range of natural conditions.

A LARGE-SEEDED VARIATION OF WILD WHEAT.

After the previous chapters of this report had been written another outdoor planting of the wild wheat was made, this time in southern California. The results were altogether different from those of the previous experiment in Texas, where the wheat made only a scanty growth and became badly infested with rust. The California planting was made at the United States Experiment Farm at Bard, Imperial County, in the Colorado River Valley, a few miles below the Laguna Dam. A first sowing, in November, was more successful than others made at later dates. The plants grew vigorously during the winter months, attained a larger size, and produced finer heads than any that were seen in Palestine. (See Pl. XII.) Instead of being limited to 15 or 20 stalks, as in Palestine, the California plants produced clusters of 50 stalks and upward. Owing to the very abundant stooling, the ground was covered with a dense mass of herbage, suggesting a possible value for forage purposes. (See Pl. XIII.) The heads began to appear early in April and some of the seed was ripe a month later. As the season of 1912 was unusually late the ripening date would probably have been three or four weeks earlier in an ordinary year.

The same general range of individual diversity appeared in California as in Palestine, though the differences became more obvious with the larger size of the plants and the better development of the heads. But in one noteworthy instance the range of variation extended quite beyond anything observed in Palestine. The plant was somewhat larger than the others and with broader leaves. It produced about 90 stalks, though only about 60 heads were secured, the others having been eaten off, probably by a marauding burro. The heads were much broader, thicker, and more compact than those of the ordinary wild wheat. (See figs. 5, 6, 7, 8, and 9.) The most important character of the new form was the larger size of the kernels. Though these were only a little longer than the kernels of the other

plants, they were much thicker and broader. The size of the kernels is shown in figure 10, *B* in comparison with those of the ordinary wild wheat (fig. 10, *A*) and the so-called Sonora wheat that is usually planted in the Southwest (fig. 10, *C*). The weight of the individual kernels in the samples shown in figure 10, *A*, *B*, and *C*, averaged, respectively, 0.032 gram, 0.071 gram, and 0.038 gram, showing that the kernels of the large-seeded variation were about twice as heavy as those of the ordinary wild wheat or of the cultivated wheat growing in the same place. The average of 381 kernels of the same stock of imported seed which was used in sowing the experimental plat at Bard was only 0.022 gram per kernel, or only about one-third as heavy as the kernels of the new variation. (See p. 22.) The average weights of thoroughly dried kernels of 13 heads of the variation ranged from 0.054 gram to 0.073 gram with a general average of

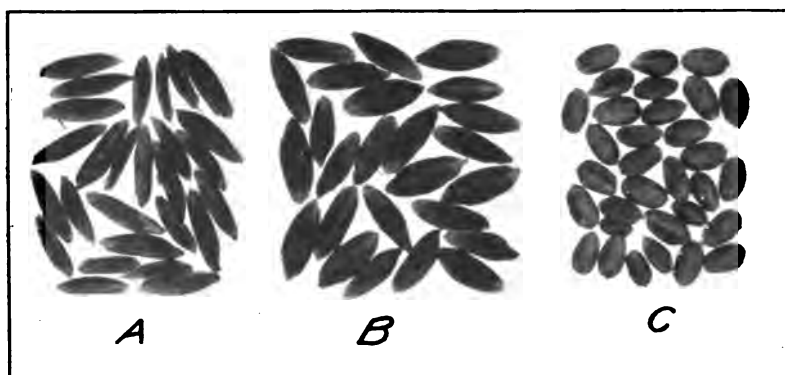


FIG. 10.—Wheat kernels. *A*, Wild wheat, showing usual size; *B*, large-seeded variation of wild wheat; *C*, Sonora wheat grown in the same locality at Bard, Cal. (All natural size.)

0.062 gram for a total of 318 kernels. The average number of kernels per head was 24.46.

The seeds are not only larger than those of the ordinary wild wheat but are more uniform in size. Each spikelet contains two full-sized kernels instead of one large and one small kernel as in the wild wheat. Moreover, there are indications of a tendency toward a further increase of the number of kernels in a spikelet, for three of the heads had one or more of the spikelets with three kernels instead of only two.

Several other differences may be considered as consequences of the larger size of the kernels. Spikelets with two or three broad seeds become, of necessity, much wider than those that contain only one or two of the narrow, slender seeds of the wild wheat. The glumes of the broad spikelets not only spread farther apart, but are of a somewhat different shape. Perhaps as a result of greater pressure exerted by the broad seeds in the younger stages of growth, the

glumes become more convex or gibbous, that is, more like those of domesticated types of wheat. (See Pl. XIV.)

The greater divergence of the glumes also appears to be responsible for a stronger curvature of the awns near the base, to bring them into line with the rachis. (Pl. XV.) Such curvature might easily result from increased pressure to which the thicker heads would be subjected in the leaf sheaths in which they are inclosed during the younger stages of growth. The presence of many crumpled awns also indicates that the broad heads experience unusual difficulties in emerging from the sheaths. Figure 11 shows one of these crumpled awns on one of the lower spikelets.

The greater pressure and increased friction of the broad heads in the leaf sheaths may also be responsible for differences in the rachis. The joints of the rachis of the broad-seeded variation are shorter, thicker, and more curved than those of the ordinary wild wheat.

That so many differences in the spikelets and rachis should arise as direct mechanical results of increasing thickness of the seed seemed rather improbable when the idea at first suggested itself, but parallel differences were found to occur in the domesticated types of wheat. In some of the so-called Sonora wheat growing in a neighboring field it was noticed that some of the heads had small, narrow spikelets near the base. Such spikelets not only had the same general shape as those of the wild wheat, but had the glumes straight sided and fitted together in the same way as in the wild wheat. Even more interesting was the fact that these narrow spikelets were accompanied by a marked elongation of the joints of the rachis, much as in the wild wheat.

Still another difference of the broad-seeded variation of the wild wheat may be considered as a mechanical change. Supposing that



FIG. 11.—Head of a large-seeded variation of wild wheat, with spikelets falling apart. (Natural size.)

the rachis has to be shortened and stiffened to force the thicker heads out of the leaf sheaths, this might explain a loss or reduction of another specialized feature, the jointed structure of the rachis. In any event, the large-seeded variation, with its broader and shorter heads, shows a distinct tendency toward a firm rachis. Some of the terminal joints are ready to separate as soon as the heads are mature, as in the wild wheat, but there is a much greater tendency for half of the head to remain together. (Fig. 11.) Many of the heads remained quite unbroken until after they were picked and thoroughly dried out. Indeed, there seemed to be a difference in this respect between the individual heads of the large-seeded plants. Those that were longer and more open, like those of the wild wheat, seemed to have a more fragile rachis than the shorter and more compact heads.

The importance of the new variation as a step in the acclimatization of the wild wheat will depend, of course, on the constancy of the characters, which must be determined by planting the seed and raising the progeny. But whatever its nature or cause, the existence of such a variation is a significant fact, for it shows that other departures from the wild type are to be expected. If the plant represents a definite variation a few more changes of similar magnitude would mean the production of a cereal of agricultural value. But there can be no assurance regarding the behavior of the variation until further generations have been grown.

Considered even as a natural hybrid with the domesticated wheat in Palestine, the plant would be interesting as a further evidence of cross-fertilization. But the jointed rachis and other characters do not favor the idea of hybrid origin. An alternative possibility is that the variation was present in the seed that was planted and is to be considered merely as an extension of the already very wide range of variation known to exist in the wild wheat in Palestine. If this be true, it becomes the more important to know the complete range of variation of the species in its natural state. Other forms of equal or greater interest might be found. A third possibility is that a new variation has been induced by transferring the plant to the new conditions to which it was exposed in southern California. All of the remaining seed of the imported stock was sorted over carefully, but nothing was found that in any way resembled the broad spikelets of the large-seeded variation. But this affords no conclusive proof that an ordinary narrow spikelet gave rise to the new variation. It would be necessary to make a thorough search of the district from which the seed came before it would be safe to conclude that a new variation had been induced by the transfer to California.¹

¹ Mr. Aaronsohn is inclined to the opinion that the large-seeded variation represents a natural hybrid with the domesticated type of wheat, similar forms having appeared among his artificial crosses.

ECONOMIC PROSPECTS OF THE WILD WHEAT.

Whether the wild wheat of Palestine will have a direct agricultural value, in addition to the light thrown upon general problems of heredity and breeding, is still doubtful. For reasons already explained, the plant is not well adapted to cultivation as a grain crop in its present form and can scarcely be utilized in this way unless varieties can be developed with heads that hold together instead of falling apart into separate spikelets, as shown in figure 11.

Apart from its possibilities of developing into a cereal, the ability of the plant to maintain itself in extremely rocky soils might give it value as a winter pasture grass in some of the dry regions of the Western States, especially in limestone districts. The firm, indehiscent, well-armed spikelets would undoubtedly protect the seed against many small birds and insect enemies that would interfere with the natural propagation of any ordinary large-seeded cereal grass and might enable the wild wheat to maintain and extend itself naturally when once established in favorable places. On the other hand, a careful study of the habits of the plant should be made before giving it any opportunity to escape from cultivation. Though nothing was noticed in Palestine to indicate such a danger, it is not inconceivable that the wild wheat might, under some conditions, invade cultivated lands and become an undesirable weed. It is a well-known fact that harmless plants sometimes become harmful weeds when introduced into a new country.

In a level region with strong winds the spikelets of the wild wheat might be blown long distances and then bury themselves in the ground, to wait indefinitely until rain or irrigation gave opportunities for germination. The plant would probably behave in the entire southwestern region strictly as a winter annual, and this would doubtless make it very easy to eradicate from any cultivated land.

The wide range of diversity manifested by the wild wheat makes it evident that the full possibilities of utilizing the species are not to be determined without a much wider and more thorough study. Unless the range of variation of the species is known there can be no estimate of the possibilities of selective improvement. Even from the standpoint of historical and biological interest it is worth while to determine whether such types as the domesticated wheats or emmers can be secured by selection from this wild species.

There is also the possibility pointed out by Mr. Aaronsohn of utilizing the wild wheat in making useful hybrids with domesticated types. As this work is now in progress at the Jewish Agricultural Experiment Station at Haifa, Palestine, some indication of its pros-

pects can probably be gained within two or three years. Though hybrids seem to be much less useful in field crops than in horticultural plants, they are likely to have more value in plants capable of regular self-fertilization like wheat than in those that remain open to continuous crossing, as in the case of cotton. It is not yet known whether crosses of the wild wheat with domesticated varieties would be adapted to self-fertilization, but there is a fair prospect of Mendelian results in such cases where a desired character represents an absence or failure of expression of a specialized feature, such as the joints of the rachis or the mechanism that opens the glumes of the wild wheat.

The chief advantages that are to be sought by the making of such hybrids are increased vigor, fertility, and rust resistance. No indications of rust or other diseases were found in the wild wheat in Palestine or in the very diverse cross-fertilized stocks of the domesticated wheat. Though this apparent immunity may have been due to other causes, the possibility of an inherent difference in this respect between self-fertilized and cross-fertilized forms is worthy of consideration. The acclimatization of cross-fertilized varieties of wheat may open the way to a regular utilization of the increased vigor and fertility that appear in artificial hybrids between self-fertilized varieties.

CONCLUSIONS.

As the wild wheat of Palestine is of interest from different standpoints it may be convenient to have separate summaries of the facts relating to the various aspects of the subject.

CHARACTERS AND HABITS OF WILD WHEAT.

The wild wheat is widely distributed on the slopes of the Anti-Lebanon range of mountains in northern Palestine and Syria, where it behaves as a truly indigenous plant. The finding of the same plant under very different conditions in the Jordan Valley, as reported by Mr. Aaronsohn, indicates that it is not localized about Mount Hermon, but probably has a much wider natural distribution, yet to be delimited.

The wild wheat is especially abundant on limestone formations, where it often appears as the dominant grass. On the volcanic areas that are often abruptly intruded among the limestones the wild wheat is usually absent or is represented by only scattering individuals. The causes of this apparent limitation of the wild plant are not yet understood.

The wild wheat comes to maturity in the spring, at the same time as the domesticated wheat. At the end of June, in the season of 1910, nearly all the plants had passed the flowering stage and on many of them the seeds were fully mature and beginning to fall. The plants that grew in moist places or in the plowed fields were somewhat later than the others and showed a distinct tendency to successive development of the heads, some of which were still in the flowering stage.

In addition to the differences that could be ascribed to external conditions there was a notable diversity among the individual plants, especially in colors, spines, hairs, and bristles of the glumes. In the shapes of the heads the wild wheat showed much less diversity than the cultivated wheat of Palestine.

Adaptations for cross-fertilization were found in the wild wheat and also indications of similar characters in the primitive unselected stocks of the domesticated wheat grown in the same part of Palestine. Some of the flowers have their anthers exerted before the shedding of the pollen, and, conversely, in some flowers the glumes spread apart so that pollen is admitted before the anthers mature. The exertion of the stamens allows the pollen to be scattered by the wind. The spreading of the glumes permits wind-blown pollen to reach the stigmas.

Indications of sexual dimorphism were found. Some of the plants had distinctly proterogynous flowers, with the stigmas exposed before the maturity of the anthers, while on other plants the flowers appeared to be proterandrous, the anthers being exerted while the stigmas were still only partly developed.

The production of seed in heads that have not emerged from the sheaths shows that some of the wild wheat is capable of self-fertilization, like the domesticated wheats. It is from such forms with simultaneous development of stamens and pistils that the self-fertilized wheat varieties of northern Europe may have been derived. The selection of proterogynous forms would afford a means of developing cross-fertilized varieties.

The joints of the rachis are highly specialized. They separate from each other at maturity, but remain permanently attached to the spikelet, forming beaklike organs barbed on each side with stiff bristles. The function of the specialized joints is to facilitate the movements of the spikelets, which creep into crevices of rocks or bury themselves in the soil. The strongly barbed awns also assist in the dissemination of the spikelets.

The spikelets never develop more than two seeds, often only one. The seeds of the same spikelets are usually unequal and the smaller

one usually fails to germinate. The smaller seed is produced by the lower flower of the spikelet, which has the larger awn.

The seedlings usually germinate with three radicles, which emerge from both faces of the spikelet. Four or five radicles sometimes appear.

The finding of spikelets with intermediate characters between the wild wheat and *Aegilops* indicates the formation of natural hybrids.

THE PROBLEM OF THE WILD PROTOTYPE.

Though there is no reason for any further doubt of the existence of a wild type of wheat in Palestine, equal certainty can not be claimed for the idea that the Palestine wild wheat is the ancestor or true prototype of the domesticated types of wheat. It is still doubtful whether all the cultivated types of wheat arose from a single wild species or from different species.

The wild wheat of Palestine shares some of the characters of emmer (*Triticum dicoccum*) and einkorn (*Triticum monococcum*), but should be considered as a distinct new species, to which the name *Triticum hermonis* may be applied, in allusion to its native habitat on the slopes of Mount Hermon.

A very diverse unselected stock of domesticated wheat (including forms referable to *Triticum aestivum* and *T. durum*) is cultivated in the region of Mount Hermon and grows frequently as a spontaneous or escaped plant. But even in its most degenerate condition the cultivated type of wheat shows no tendency to revert or approximate to the characters of *Triticum hermonis*. Some of the depauperate plants gave indications of the same habits of cross-fertilization as in the wild wheat.

Though the wild wheat of Palestine possesses all the characters that the European specialists expected to find in the primitive ancestor or prototype of the domesticated wheat, these characters might also be expected to occur in any wild relative of the wheat plant and do not afford ground for a final conclusion regarding the relationships that exist between the wild wheat of Palestine and the domesticated cereals.

The economic value of this new wild relative of the cultivated wheats does not depend on its being the original progenitor or prototype. Its relationship is at least close enough to permit crossing or to justify an attempt at developing new types of cereals adapted to special conditions, such as those of our Southwestern States.

FACTORS OF HEREDITY AND BREEDING.

The wild wheat of Palestine shows a wide range of individual diversity (heterism), like the wild relatives and unselected stocks of

other domesticated plants. This condition of diversity is to be explained by the presence of specialized adaptations for cross-pollination, as well as by the absence of methodical selection.

The cultivated wheat of Palestine shows the same condition of individual diversity as the wild wheat and retains the same facilities for cross-pollination by the exertion of the anthers and the spreading of the glumes. Instead of being naturally restricted to self-fertilization, the wheat plant seems to have been specially adapted for cross-fertilization in a dry climate.

The condition of self-pollination found among domesticated wheats is not a primitive condition but has been reached through a reduction or loss of adaptations for crossing, like those possessed by the wild type. Though in some of the domesticated varieties the cross-fertilizing adaptations may have been completely lost, certain forms of domesticated wheat still remain capable of natural crossing in the same manner as the wild wheat.

The habit of self-fertilization found among our cultivated varieties of wheat is no longer to be considered as an original ancestral condition. Analogies with other plants suggest that an eventual decline in vigor, fertility, and disease resistance may be expected in varieties of wheat that are limited to self-fertilization.

AGRICULTURAL APPLICATIONS.

The wild wheat of Palestine is a hardy plant, in the sense of being able to exist under a wide range of natural conditions. Its natural distribution extends from the higher slopes of Mount Hermon, that are covered with snow in the winter, to the parched walls of the Dead Sea Valley.

The behavior of wheat in Palestine suggests the possibility of acclimatizing new types of wheat adapted to arid subtropical districts of the Southwestern States. This possibility relates not only to the wild wheat, but to the primitive unselected stocks of wheat that are grown in arid subtropical districts of Palestine and adjacent regions.

The native wheat fields of Palestine produce excellent crops in spite of the fact that the individual plants show a wide range of differences, as bearded or beardless heads, very open or closely crowded spikelets, white, red, or black chaff, with smooth, pruinose, or velvety surfaces, dark or light grains, etc., from which an endless number of varieties could be separated by selection.

The occurrence of this primitive diversity under conditions that admit of normal cross-fertilization indicates that the same method of acclimatization can be applied to wheat as to diverse types of cotton or other cross-fertilized crop plants. The full range of adaptation of a widely diversified type can be obtained, instead of the limited

possibilities of self-fertilized strains selected on the basis of adaptation to entirely different conditions in northern Europe.

Consideration should also be given to the possibility of securing increased rust resistance in wheat by the acclimatization of more vigorous cross-fertilized types or by using such types or the wild species to produce hybrids with American varieties.

Cross-fertilized varieties of wheat would be subject to injury from wet weather at the time of flowering, but this danger would not be serious under the climatic conditions of the Southwestern States or of the Great Plains area.

There is also the possibility of utilizing the wild wheat as a self-sown forage plant, either in cultivation or by allowing it to escape and establish itself on grazing lands in California or other Southwestern States. In view of the fact, however, that the seeds are specially adapted for dissemination the possibility of the plant escaping and becoming a weed will have to be carefully considered before any general distribution can be advised, even for experimental purposes.

DESCRIPTION OF PLATES.

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WILD WHEAT GROWING AMONG NUMMULITIC LIMESTONES, BETWEEN ROSH PINAR AND THE LAKE OF GENNESARET (BAHR TABARIYEH), PALESTINE.



SITUATIONS WHERE WILD WHEAT THRIVES.

FIG. 1.—ON JEBEL KANAAN, ABOVE ROSH PINAR.

FIG. 2.—BETWEEN EL HADR AND ARNY.

FIGS. 3 AND 4.—NEAR MEJDEL ESH SHEMS.



SPONTANEOUS FORMS OF DOMESTICATED WHEAT FROM VOLCANIC SOILS AT EL HADR,
PALESTINE.
(Natural size.)



DEPAUPERATE PLANTS OF DOMESTICATED WHEAT FROM A CULTIVATED FIELD ON THE SLOPES OF MOUNT HERMON ABOVE ARNY, ADJACENT TO WILD WHEAT.

(Natural size.)



HEADS OF WILD WHEAT GROWN AT BARD, CAL., WITH ANTHERS EXTRUDED AND GLUMES SPREAD AT THE TIME OF FLOWERING. AWNS CUT OFF BEFORE PHOTOGRAPHING.

(Natural size.)



TERMINAL SPIKELETS OF AEGILOPS (*A*) AND SUPPOSED HYBRID BETWEEN WILD WHEAT AND AEGILOPS (*B*).

(Magnified nearly 2 diameters.)



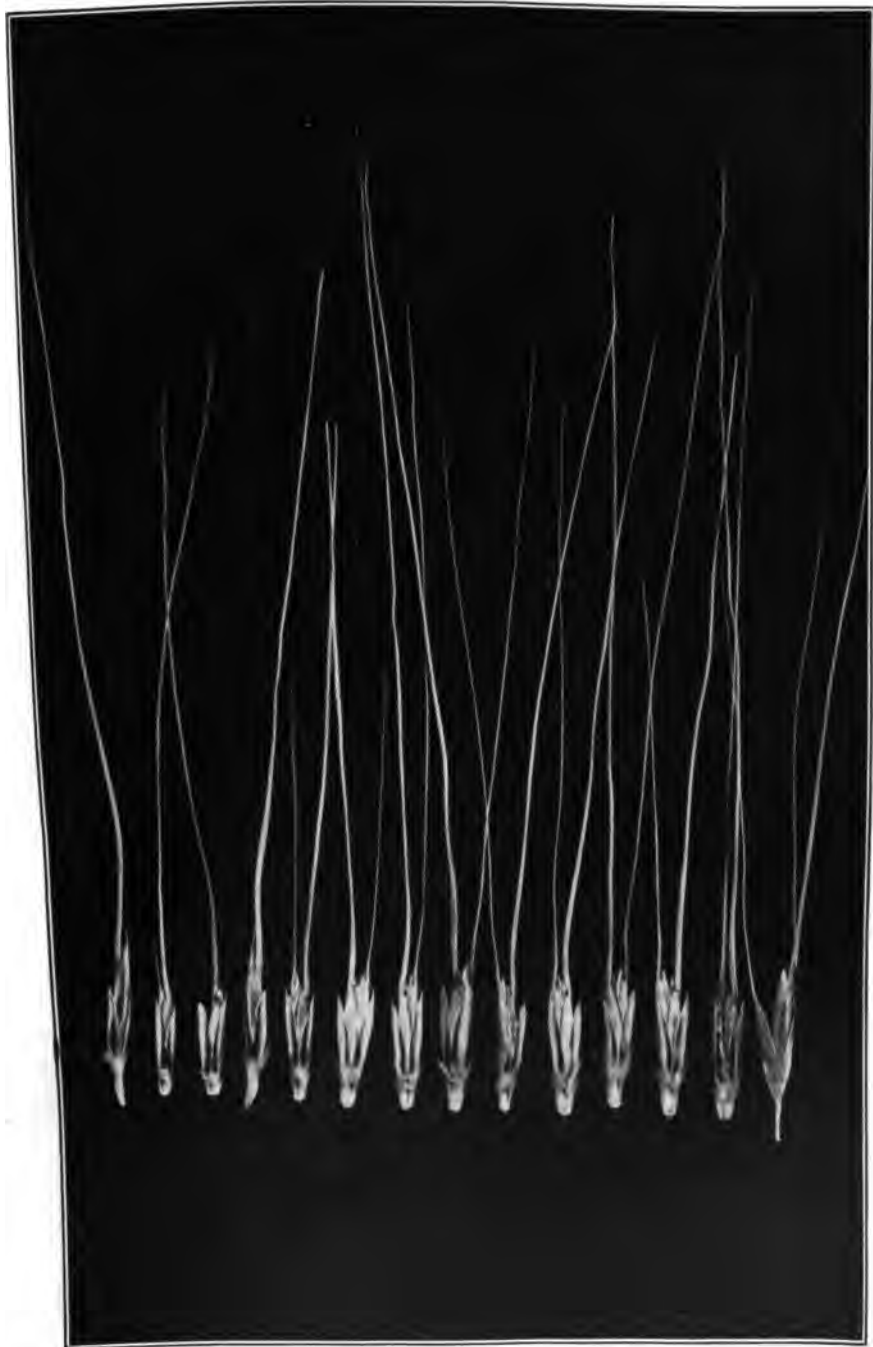
SPIKELETS OF AEGILOPS OVATA AND SUPPOSED NATURAL HYBRID BETWEEN AEGILOPS AND WILD WHEAT.

FIGS. 1 AND 2.—AEGILOPS OVATA, FRONT AND SIDE VIEWS.
FIGS. 3 AND 4.—SUPPOSED HYBRID, FRONT AND SIDE VIEWS.
(Magnified about 6 diameters.)



LOCAL VARIETY OF WILD WHEAT FROM KHAN JUBB YUSEF, PALESTINE, NEAR
THE LAKE OF GENNESARET, SHOWING DENSELY HAIRY GLUMES.

(Natural size.)



LOCAL VARIETY OF WILD WHEAT FROM THE SLOPES OF MOUNT HERMON, ABOVE ARNY, ALTITUDE ABOUT 4,000 FEET, SHOWING NARROW SPIKELETS AND SMOOTH GLUMES.

(Natural size.)



A DIVERSE STOCK OF WHEAT GROWN BY THE PIMA INDIANS NEAR SACATON, ARIZ.

(Natural size.)



DIVERSE TYPES OF CULTIVATED WHEAT FROM EL HADR, PALESTINE.
(Natural size.)



HEADS OF AN ORDINARY FORM OF WILD WHEAT GROWN AT BARD, CAL.
(Natural size.)



FIG. 1.—PART OF THE EXPERIMENTAL PLAT OF WILD WHEAT AT BARD, CAL., SHOWING DENSE FOLIAGE.



FIG. 2.—HEADS OF WILD WHEAT IN EXPERIMENTAL PLAT AT BARD, CAL.
(Photographed by Mr. L. H. Dewey.)



HEADS OF A LARGE-SEEDED VARIATION OF WILD WHEAT GROWN AT BARD, CAL
(Natural size.)



SPIKELETS OF WILD WHEAT GROWN AT BARD, CAL.

FIG. 1.—FOUR SPIKELETS OF ORDINARY FORM OF WILD WHEAT.

FIG. 2.—THREE SPIKELETS OF LARGE-SEEDED VARIATION.

(Natural size.)

Issued May 6, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 275.

WILLIAM A. TAYLOR, *Chief of Bureau.*

APPLES AND PEACHES IN THE OZARK REGION.

BY

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AND

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1913.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 20, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "Apples and Peaches in the Ozark Region" and to recommend that it be published as Bulletin No. 275 of the series of this Bureau. It was prepared by Mr. H. P. Gould, Pomologist in Charge, and Mr. W. F. Fletcher, Scientific Assistant, Fruit District Investigations, and has been submitted by Mr. A. V. Stubenrauch, Pomologist in Charge of Field Investigations, with a view to its publication.

The subject matter of this manuscript is coordinate in its general character and in the method of treatment with two bulletins previously issued, namely, Nos. 135 and 194. No. 135 relates to orchard fruits in the Piedmont and Blue Ridge regions of Virginia and the South Atlantic States. Summer apples in the Middle Atlantic States are discussed in No. 194. In the present bulletin, as in the two previous ones, the viewpoint is that of the adaptability of fruit varieties to the conditions in the region under discussion. This work constitutes a part of the fruit district investigations of this Bureau.

During the course of the investigations in the Ozark region the writers have come in contact with a large number of fruit growers who have aided very materially in the work. In fact, without the willing and hearty cooperation of fruit growers it would be impossible to carry on this line of investigation. The bulletin was read in manuscript by members of the Missouri and Arkansas experiment-station staffs. The criticisms and suggestions offered by them have been of much value, especially in certain particulars.

To those who have thus contributed to the end in view the writers gladly acknowledge their indebtedness.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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APPLES AND PEACHES IN THE OZARK¹ REGION.

INTRODUCTION.

The past two or three decades have witnessed a remarkable development and extension of the fruit industry. In fact, the growth during comparatively recent years which has resulted in its present magnitude constitutes one of the striking features of the agriculture of the United States. Much of this development has taken place along safe and conservative lines. But the extensive planting of orchards in a region whose natural advantages have been overestimated or over-exploited has been too frequent. Probably in most of these instances the development of orchards has been primarily a land-selling proposition rather than a carefully planned fruit-growing project.

In this expansion of the commercial fruit industry of the country the Ozark region has held a conspicuous place. The numerical showing of apple and peach trees within this region (Pl. I) at different census periods is shown in Table I.

TABLE I.—*Number of apple and peach² trees of bearing age in the Ozark region at different periods.*

Period.	Missouri.		Arkansas.		Oklahoma. ³	
	Apple.	Peach.	Apple.	Peach.	Apple.	Peach.
Eleventh Census, 1890.....	2,501,438	1,068,583	1,600,501	1,635,965	.....	.....
Twelfth Census, 1900.....	8,503,372	2,068,494	6,391,442	2,277,627	563,096	219,762
Thirteenth Census, 1910.....	6,660,761	3,007,906	6,913,903	4,408,952	249,537	362,446

¹ An interesting explanation of the origin of this name is as follows: "The origin of the name 'Ozark' is given by Mr. Featherstonhaugh in his book entitled 'Excursions through the Slave States,' in 1834-35, p. 63. He says: 'It was the custom of the French Canadians to abbreviate all their names. If they were going to the Arkansas mountains they would say that they were going 'Aux Arcs,' and thus these highlands have obtained the name of Ozarks from American travelers.'"—See Shepard, E. M., "A report on Greene County," in Geological Survey of Missouri, vol. 12, pt. 1, p. 17.

² Nectarines are grouped with peaches in the census statistics, but in the Ozark region the number of nectarines is so small as to be negligible.

³ It should be explained that there are no statistics for Oklahoma prior to the Twelfth Census, and that those taken from the Twelfth Census were obtained prior to the admission of Oklahoma and Indian Territories into the Union as one State. The figures for 1900 are those for the Cherokee and Choctaw Nations in the Indian Territory. Those divisions correspond fairly well to the portion of the Ozark uplift which is in Oklahoma. The figures from the Thirteenth Census apply to the counties in eastern Oklahoma which are shown on the map and which are definitely within the region under consideration. The statistics relating to Oklahoma are therefore not strictly comparable, though the sections covered are so nearly the same that the figures are of use in a relative way.

The statistics in Table I are largely self-explanatory, as they plainly show the numerical increases and decreases in the several periods to which they apply. The cause of the decrease in the number of apple trees in Missouri and Oklahoma in the decade from 1900 to 1910 will become apparent in the discussions which follow; but the figures relating to Missouri apparently do not show the full extent of the decrease, as it is commonly said that for several years following 1900 the planting of fruit trees, especially apple trees, was fully as rapid as at any previous period. The statistics for 1900, therefore, do not show the maximum number of trees of bearing age which existed in the Missouri portion of the Ozarks during the decade following the Twelfth Census.

It would perhaps be difficult to ascribe to definite influences the rapid expansion of fruit culture in this region, especially in Missouri and Arkansas, during the period from 1890 to 1900. Without doubt, however, an influence which contributed largely to the early impetus in the planting of apples was the very satisfactory prices obtained in the late eighties for the abundant crops produced on the comparatively small number of trees then in bearing. This was a period when there were relatively light crops of fruit in the older apple-producing sections of the East. Once given the impetus, the rapid growth is not difficult to explain. During the years of most rapid development the fruit-growing possibilities of the Ozark region were widely advertised, not only in this country but also abroad.

The distribution of the apple and peach trees of bearing age in the Ozark region by counties, as shown in the Thirteenth Census (1910), is indicated in Table II.

TABLE II.—*Number of apple and peach¹ trees of bearing age in the Ozark region, by counties, as shown by the Thirteenth Census.*

ARKANSAS.

County.	Apple.	Peach.	County.	Apple.	Peach.	County.	Apple.	Peach.
Baxter.....	41,590	46,270	Izard.....	39,280	60,751	Saline.....	33,414	56,153
Benton.....	2,465,870	536,208	Johnson....	144,352	321,560	Scott.....	42,469	69,606
Boone.....	233,102	161,368	Logan.....	113,401	162,210	Searcy.....	90,453	83,206
Carroll.....	225,686	95,100	Madison....	397,155	68,143	Sebastian...	93,059	419,561
Cleburne....	37,886	45,295	Marion.....	35,299	40,923	Stone.....	63,850	39,876
Conway.....	95,673	74,833	Montgomery	25,677	45,420	Van Buren..	130,634	61,037
Crawford....	160,726	603,683	Newton.....	83,095	54,906	Washington.	1,793,645	245,187
Faulkner....	30,958	67,373	Perry.....	8,238	20,843	Yell.....	29,018	145,069
Franklin....	73,793	168,053	Pike.....	36,887	179,126			
Fulton.....	53,813	138,145	Polk.....	143,554	138,034			
Garland....	27,725	41,580	Pope.....	113,157	122,524			
Hot Spring..	25,114	52,664	Pulaski....	25,330	44,243	Total..	6,913,903	4,406,962

¹ See footnote (2) to Table I.

TABLE II.—*Number of apple and peach trees of bearing age in the Ozark region, by counties, as shown by the Thirteenth Census—Continued.*

MISSOURI.

County.	Apple.	Peach.	County.	Apple.	Peach.	County.	Apple.	Peach.
Barry.....	410,896	191,845	Jasper.....	123,311	28,122	Reynolds...	41,509	22,299
Barton.....	157,337	27,796	Laclede.....	258,978	57,661	St. Clair....	86,428	37,860
Benton.....	41,902	42,508	Lawrence...	234,232	66,036	St. Francois.	50,569	30,132
Camden.....	87,260	35,421	McDonald...	243,620	97,464	Shannon....	73,566	42,425
Cedar.....	121,961	45,840	Madison....	35,188	30,634	Stone.....	75,758	72,119
Crawford...	270,309	31,046	Marion.....	91,958	35,298	Taney.....	26,044	80,668
Dallas.....	140,265	31,093	Miller.....	82,002	47,292	Texas.....	291,575	125,691
Dent.....	240,119	28,254	Morgan....	56,899	24,445	Vernon.....	200,936	48,418
Douglas....	132,386	81,978	Newton....	289,159	72,907	Washington.	47,624	41,771
Franklin....	116,975	66,112	Oregon.....	92,138	463,609	Webster....	624,638	78,031
Greene.....	501,213	126,960	Ozark.....	26,097	53,095	Wright.....	351,922	120,135
Hickory....	69,007	31,478	Phelps.....	153,902	38,530			
Howell.....	474,560	424,269	Polk.....	194,043	54,464	Total..	6,660,761	3,007,906
Iron.....	22,577	20,343	Pulaski....	121,898	43,357			

OKLAHOMA.

Adair.....	39,311	21,645	Hughes.....	16,897	17,381	Pontotoc....	14,966	41,201
Cherokee....	30,643	10,194	Latimer....	732	2,829	Pushmataha	2,240	8,161
Coal.....	4,068	12,121	Le Flore...	9,776	41,677	Sequoyah...	13,610	49,770
Delaware....	63,636	18,754	McCurtain.	2,280	8,248			
Garvin.....	11,512	35,624	Murray....	5,980	24,005	Total..	249,537	362,446
Haskell....	9,692	24,772	Pittsburgh.	24,194	46,064			

On account of the importance of the fruit industry in the Ozark region and the transition period through which it was passing, the Bureau of Plant Industry of the Department of Agriculture began in 1903 a study the object of which was to determine as far as possible (1) the exact behavior of the different fruit varieties, especially of the apple and peach, in different parts of the region, (2) the conditions under which they attain their highest degree or a satisfactory degree of perfection, and (3) the suitability of each variety for the purpose intended. The final object is to aid in the introduction of sorts which may prove more profitable and satisfactory than those now being grown.

In 1903 a brief period was spent in getting in touch with the growers and locating some of the more important orchards, thus facilitating subsequent investigations. From 1904 to 1908, inclusive, a considerable portion of each season, from July to September, was given to this work. Subsequent observations have also been made in certain sections.

This bulletin is devoted principally to a discussion of the results of these investigations. In order that a description of the behavior of a variety may have real significance it must be interpreted in terms of the conditions under which the variety is grown. Accordingly, there follows a somewhat comprehensive description of the region studied and an account of the conditions existing therein which have an important bearing on its fruit industry.

A "transition period," through which the fruit industry of the Ozark region was passing, has been mentioned. This applies especially to the matter of varieties. Most regions in which large apple interests have been developed in the past have gone through such a period. It is a natural consequence of the status of our knowledge, or rather lack of knowledge, of the adaptability of varieties and their relative value when grown in different regions or under different conditions.

While a large portion of the apple and peach trees in the Ozark region consists of comparatively few varieties, it is also true that a great number of varieties, especially of apples, are grown in commercial quantities. The experience gained during past years shows that if the plantings were now to be renewed a large percentage of these varieties would probably be eliminated, and of the small number comprising the more important sorts the proportion of trees of the different varieties would be changed in many orchards. Certain varieties of little value in some sections of the Ozarks could almost surely be planted in other parts of the region with satisfaction. Still other sorts now but little known or entirely unknown to the orchardists there could probably be substituted with profit for some that are more or less commonly planted.

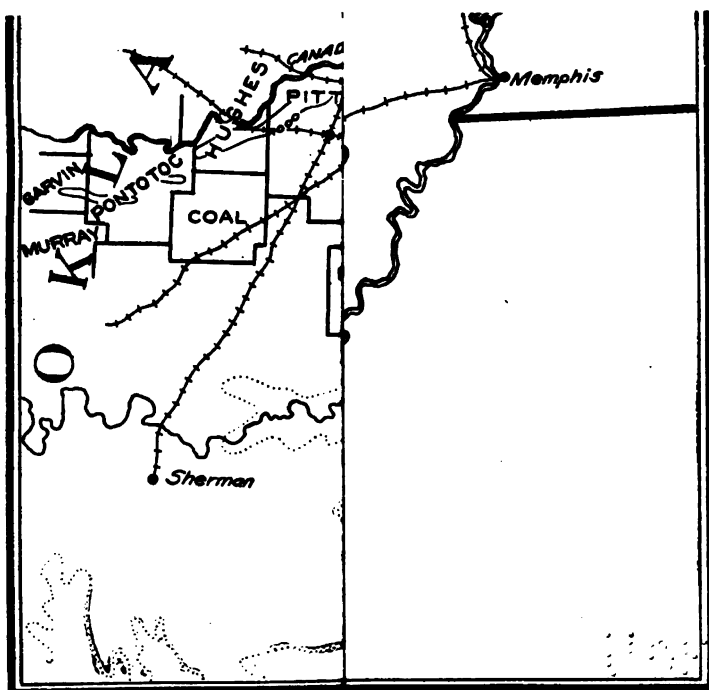
The greater the extent to which information regarding the adaptability of varieties can be made available for the guidance of fruit growers the more will it become possible to eliminate this "transition period" with regard to varieties for planting in the extension of fruit growing into new regions.

DESCRIPTION OF THE OZARK REGION.

LOCATION AND TOPOGRAPHY.

The accompanying map (Pl. I) shows the counties in Missouri, Arkansas, and Oklahoma which comprise the portion of the Ozark region to which the following discussion of apple and peach varieties is intended to apply. The region includes a large part of the southern half of Missouri, northwestern Arkansas (about one-third of the entire area of the State), and a relatively small section of eastern Oklahoma. The area does not include the entire Ozark uplift, though the portion of this formation which lies outside of its limits is relatively small.

The elevation above sea level of much of the country surrounding the Ozark uplift is from 500 to 800 feet, and the surface is gently rolling. A large portion of the Ozark region has an altitude of 1,200 to 1,500 feet, and some sections of it are distinctly mountainous. The culminating altitudes of the entire region are in the range of Ouachita Mountains south of the Arkansas River, in which the sum-



mit of Magazine Mountain reaches an elevation of 2,889 feet—the highest point between the Appalachian and the Rocky Mountains.

As elevation is one of the chief factors to be considered in investigating the behavior or adaptability of fruit varieties, it has been necessary for the purposes of the present consideration to adopt more or less arbitrarily some line based on elevation as the boundary of the Ozark uplift. A contour line encompassing the territory which has an elevation exceeding 900 feet serves the end in view. The counties lying wholly or partly within this boundary and belonging to the region under consideration are named on the accompanying map (Pl. I). Several counties bordering on the Missouri River and lying partly within this boundary are not shown on the map, for the reason that the principal orchard interests in them are located in sections that are distinctly outside the Ozark formation. Some of the included areas have relatively low elevations, particularly along the rivers and larger streams.

The contour lines which appear on the map will materially assist the reader in obtaining a general idea of the topography of the region and the elevation of different sections of it, both actual (above sea level) and relative (in comparison with the surrounding country). The interval between the contour lines represents a difference of 500 feet in elevation.

An excellent account of the Ozark region, in which the conspicuous topographic features which are of importance in the present connection are very clearly described, appears in the Annual Report of the Missouri Geological Survey for 1894, from which the following paragraphs are quoted:¹

Surface relief.—While there is simplicity and similarity in general make-up of the different portions of the Ozark uplift, the fundamental structural and topographical effects presented in the several parts are sufficiently distinct to enable several well-defined districts to be made out. This fact has been recognized both by the inhabitants and by those who have visited the region, and in consequence various names have been given to the different sections. The most prominent titles among those which deserve mention are Shawnee Hills, located in the extreme east, chiefly in Illinois; St. Francois Mountains, in eastern Missouri; the Ozark Mountains proper, the Boston Mountains, and the Ouachita system in the Southwest. These various "mountain" systems, which define geographically the subdivisions of the uplift, are characterized by certain peculiarities, of which none are more striking than the various phases of topography. The extremities of the disturbed region are similar, and consist of a series of ridges which in a general way are parallel to one another. The middle is a typical high plateau, whose margins are deeply trenched by swift-running streams.

Shawnee Hills.—Before it merges into the Mississippian Plain, the Ozark Plateau is broken up toward the eastward into a number of rather well-pronounced ridges. These

¹ Keyes, C. R. Characteristics of the Ozark Mountains. Annual Report, Missouri Geological Survey, vol. 8, 1894, pp. 320-352.

ridges are cut across by the Mississippi River at various points between St. Louis and Cape Girardeau. * * *

St. Francois Mountains.—Southeastern Missouri has long been known as a highland district, but the title, St. Francois Mountains, is of very recent application. The term is one which has been needed to designate the eastern part of the Ozark uplift in Missouri. It is a name which is peculiarly fitting, owing to its long association with the principal river and a county in the region.

The most striking peculiarity of the St. Francois group as distinguishing it from other parts of the general uplift is the absence of any systematic arrangement of the surface features as the result of orogenic movements, and as is usually discernible in mountainous districts. Isolated peaks, large and small, constitute the prevailing type of topographic expression, and these rise one behind another with no regularity, often clustered here and there into groups of two or three, sometimes several in a row, forming a short irregular ridge. The hills or peaks rise 500 to 800 feet above the valleys which separate them, and have an elevation above tide level of 1,200 to 1,800 feet. * * *

Ozark Plateau.—The region with which the word Ozark has been most widely associated comprises southern Missouri and northwestern Arkansas. The term has also been applied to the extreme eastern part of the uplift, and even to the western extremity of the Ouachita system. The Ozark Mountain region proper includes (1) a broad plateau which rises to a height of over 1,500 feet above the tide level, and (2) a broad marginal zone so deeply trenched by watercourses as to make the term mountainous very applicable. In all its features, the district presents a marked contrast to the other portions of the uplift. In the plateau, the streams take their rise and flow in opposite directions down the general slopes in ever-deepening trenches. * * *

Boston Mountains.—This name has been used to designate a range of steep-sided elevations which form the watershed in western and central Arkansas, between the White and Arkansas Rivers. They extend nearly parallel to the latter stream halfway across the State. The crest is from 1,000 feet above sea level in the eastern part to more than twice this height in the central and western portions, or from 600 to 800 feet above the waters which wash their bases. * * *

Ouachita Mountains.—South of the Arkansas River is a series of mountain ranges trending west from Little Rock into the Indian Territory [Oklahoma]. To the most southerly ranges Branner has given the name Ouachita Mountains; but more recently Griswold has extended the meaning so as to cover the entire number of ranges. The system consists of numerous anticlinal ridges which lie nearly parallel to one another. They rise from 500 to 1,000 feet above the valleys on either side, and from 1,600 to 2,100 feet above the sea level. * * *

The marked structural differences existing in the elevated area south of the Arkansas River, as compared with that north of the stream, have given rise to the suggestion that the two districts are distinct units of deformation, and that the long slope of the broad river valley forms the southern slant of the Ozark dome.

The elevation of specific points is given in Table III. The place names are arranged, in general, from east to west and from north to south.

TABLE III.—*Altitudes of representative points in the Ozark region.*

State and county.	Locality.	Authority. ¹	Elevation. Feet.
Missouri:			
St. Francois.....	Bismarck.....	Missouri Pacific R. R.....	1,025
Wayne.....	Piedmont.....	do.....	504
Crawford.....	Cuba.....	St. Louis & San Francisco R. R.....	1,014
Dent.....	Salem.....	do.....	1,178
Laclede.....	Lebanon.....	do.....	1,268
Oregon.....	Thayer.....	do.....	534
Do.....	Koshkonong.....	do.....	967
Howell.....	West Plains.....	do.....	957
Do.....	Olden.....	do.....	1,237
Do.....	Willow Springs.....	do.....	1,247
Texas.....	Sargent.....	do.....	1,328
Do.....	Cabool.....	do.....	1,252
Wright.....	Mountain Grove.....	do.....	1,472
Do.....	Mansfield.....	do.....	1,488
Do.....	Cedar Gap.....	do.....	1,683
Webster.....	Seymour.....	do.....	1,650
Do.....	Fordland.....	do.....	1,601
Greene.....	Springfield.....	do.....	1,260
Morgan.....	Versailles.....	Missouri Pacific R. R.....	1,020
Polk.....	Bolivar.....	St. Louis & San Francisco R. R.....	1,066
Barton.....	Lamar.....	U. S. Coast and Geodetic Survey.....	904
Jasper.....	Carthage.....	St. Louis & San Francisco R. R.....	939
Lawrence.....	Aurora.....	do.....	1,366
Newton.....	Neosho.....	do.....	1,023
Arkansas:			
Baxter.....	Mountain Home.....	U. S. Geological Survey (topographic sheet).....	800
Do.....	Cotter.....	do.....	500
Marion.....	Yellville.....	do.....	600
Boone.....	Harrison.....	do.....	1,062
Carroll.....	Berryville.....	do.....	1,254
Benton.....	Rogers.....	U. S. Coast and Geodetic Survey.....	1,383
Do.....	Bentonville.....	U. S. Geological Survey.....	1,303
Do.....	Gravette.....	do.....	1,226
Do.....	Gentry.....	Kansas City Southern Ry.....	1,238
Searcy.....	Marshall.....	U. S. Geological Survey (topographic sheet).....	1,060
Washington.....	Springdale.....	U. S. Coast and Geodetic Survey.....	1,325
Do.....	Fayetteville.....	do.....	1,334
Do.....	Prairie Grove.....	U. S. Geological Survey.....	1,168
Do.....	Lincoln.....	St. Louis & San Francisco R. R.....	1,458
Do.....	Winslow.....	U. S. Coast and Geodetic Survey.....	1,727
Pope.....	Russellville.....	do.....	350
Johnson.....	Clarksville.....	do.....	370
Crawford.....	Rudy.....	do.....	496
Do.....	Van Buren.....	do.....	441
Yell.....	Danville.....	Choctaw, Oklahoma & Gulf R. R.....	361
Logan.....	Booneville.....	do.....	517
Sebastian.....	Hackett.....	St. Louis & San Francisco R. R.....	536
Scott.....	Waldron.....	U. S. Geological Survey (topographic sheet).....	700
Garland.....	Hot Springs (entrance, U. S. reservation).....	U. S. Geological Survey.....	607
Do.....	Hot Springs (inlet pipe, city reservoir).....	do.....	869
Montgomery.....	Mount Ida.....	U. S. Geological Survey (topographic sheet).....	700
Polk.....	Grannis.....	Kansas City Southern Ry.....	922
Oklahoma:			
Adair.....	Westville.....	do.....	1,135
Cherokee.....	Tahlequah.....	St. Louis & San Francisco R. R.....	861
Sequoyah.....	Salisaw.....	U. S. Geological Survey.....	532
Le Flore.....	Poteau.....	do.....	486
Pushmataha.....	Tuskahoma.....	do.....	571
Pontotoc.....	Ada.....	St. Louis & San Francisco R. R.....	980

¹ Data, except as noted, taken from Gannett, Henry. A dictionary of altitudes in the United States. Bulletin 160, U. S. Geological Survey, 4th ed., 1906.

Some of the points named in Arkansas and Oklahoma having relatively low altitudes represent distinctly valley conditions, and most points where a low altitude is indicated are only short distances from considerably higher elevations. For example, Danville, Ark., with an altitude of only 361 feet, is within 2 or 3 miles of an area having an elevation of nearly 1,200 feet. Hackett, Ark., which has an altitude of 536 feet, is within about 10 miles of one of the highest sections in the entire Ozark region.

SOIL.

As soil surveys of representative areas of the Ozark region between the Missouri and Arkansas Rivers have been made by the Bureau of Soils of the Department of Agriculture and the various types of soil have been described and mapped, the reader who is interested in an extended discussion of this subject should consult the publications in which these descriptions appear.¹

A considerable number of different types of soil are recognized in these soil surveys, but only two, the "Clarksville stony loam" and the "Clarksville silt loam," are of special importance in the present connection. These two types include a large proportion of the area between the rivers mentioned, and most of the orchards and other fruit plantations in these sections are growing on these soils.

The following brief accounts of these types of soil are composite descriptions condensed from the reports of the Bureau of Soils already cited:

Clarksville stony loam.—The surface soil of the Clarksville stony loam consists of gray silt or silt loam from 6 to 15 inches deep. This is underlaid by a heavier silt loam of a lighter gray, yellowish gray, or reddish yellow color, which sometimes extends to a depth of 3 feet, but more often at depths ranging from 12 to 30 inches it grades into a silty clay loam or silty clay. This lower subsoil is usually characterized by a deeper color of either red or yellow, the red being considered the more productive. In some places the subsoil grades into a distinct red clay frequently highly charged with iron.

The surface is generally loose, friable, and mellow, the stones in large measure preventing it from packing as readily as the Clarksville silt loam does under some conditions. The rock content, consisting largely of chert fragments, varies from 10 to 70 per cent. Occasionally, in small spots, the surface is entirely covered with chert fragments. This occurs especially on slopes where the fine particles of soil have been washed away, leaving only the rock fragments visible.

Clarksville stony loam has been derived largely from cherty limestones, the most resistant parts of which in the form of chert or flint still constitute a predominant feature of this soil type. Occasionally sandstones and certain other rocks are found, but they have existed in quantities relatively too small to produce any very marked effect upon the physical characteristics of the soil, except possibly in very small areas. This type of soil occupies a larger area than any other one in this region.

Clarksville silt loam.—The surface of the Clarksville silt loam consists of a loam from 7 to 14 inches deep. Its color may be a light or dark gray, or pale yellow with varia-

¹ Field Operations, Bureau of Soils, U. S. Dept. of Agriculture, 1902, Soil survey of Howell County, Missouri, with map, pp. 593-609; same, 1904, Soil survey of Webster County, Missouri, with map, pp. 845-858; same, 1905, Soil survey of Crawford County, Missouri, with map, pp. 865-878; same, 1906, Soil survey of the Fayetteville area, Arkansas, with map, pp. 587-627.

tions in some places of a brown shade. Below the surface of the soil to a depth frequently of 3 feet the material is a heavy, compact, silty loam or silty clay having a reddish or brownish color, sometimes mottled with gray.

As a rule there is a marked deficiency in organic matter throughout this soil type. Even in the woodlands the proportion of humus is very small, and this disappears rapidly with a few years of cultivation. Unlike most soils which are similar in texture to it and which are low in organic matter, the Clarksville silt loam does not become compact and hard, but remains loose and friable even under very unfavorable conditions. It has an excellent water-holding capacity and responds readily to applications of manure and to the rotation of crops with clover. On account of mismanagement it is very low in productiveness in many instances, but it is easily brought into a high state of productivity which may be readily and economically maintained.

The surface is quite free from stones except in patches. In places where it is apparent that this soil and the Clarksville stony loam are derived from much the same formations, this freedom from stone appears to be the chief difference between these two types. But this in itself gives rise to other differences of importance. The rock fragments of the Clarksville stony loam render its soil and subsoil more open, and consequently less able to withstand drought, while on the other hand the Clarksville silt loam is more subject to the effect of prolonged wet weather.

The Clarksville silt loam is second in importance, Clarksville stony loam being first, in comparison with the other types in this region, in the extent of the area which they occupy.

Occasionally there occurs in restricted areas a type of soil known locally as "prairie soil" on which orchards have been planted.

The surface of the "prairie soil" is composed of a dark colored, in some cases nearly black, loam, while the subsoil is usually similar to that of one or the other of the types described above. This type of soil occupies level tracts where little or no erosion has occurred and as a rule is not as well drained as are the others mentioned.

On account of the differences in the geological formation of the portion of this region which lies south of the Arkansas River in the Ouachita Mountain section in comparison with the section which lies between the Arkansas and Missouri Rivers, there are corresponding soil differences which should be noted.

The fragments of chert and flint rock which form such a conspicuous feature in the Clarksville stony loam are mostly absent in the arable land in the Ouachita Mountain section. Sandstones are abundant here and in many places have decidedly influenced the character of the soil, giving rise to sandy and sandy-loam types. Clay and clay loams, frequently highly impregnated with iron oxid and producing the characteristic red color due to the presence of that substance, also occur as prominent types.

That the principal soil types in the Ozark region which have commonly been devoted to apple and peach orchards are well adapted to the growing of the trees is very apparent. One of the most striking pomological features of the region is the large size of the trees for their age, in the young orchards at least until they are 10 to 15 years old, in comparison with trees of the same age in many other fruit-

growing regions, especially in the Eastern States. This unusual tree growth can not be attributed, however, to any unusual fertility of the soil, as the general farm crops grown in the region do not indicate that it is more fertile than good farming land in many other regions. It is probable that the character of the subsoil contributes very largely to the rapid growth of the trees. As a rule, in most of the types the subsoil is relatively loose and porous and generally it has considerable depth. These conditions are favorable to the development of good root systems, and it is perhaps of even greater importance that the subsoil is of such a character that it provides an exceptionally good reservoir for the storage of soil moisture.

CLIMATE.

CLIMATIC CONDITIONS A LIMITING FACTOR IN FRUIT GROWING.

In any comprehensive investigation of a given region with regard to its possibilities for fruit growing and in the consideration of all questions connected therewith relating to varieties, the climatic conditions of the region call for the most critical attention. While it may not be entirely correct to say that climate is more often the "limiting factor" in fruit production than anything else, yet it is hardly possible to overestimate the importance of climatic conditions in their relation to fruit culture.

The more important climatic factors limiting profitable fruit production may be stated as follows:

The temperature factor.—(1) Excessively low during the dormant period, causing injury to fruit trees or buds; (2) excessively high during the dormant period, causing buds to swell and become tender, making them susceptible to injury later even by seasonable temperatures; (3) excessively low during the blossoming period, resulting in destructive frosts, or sometimes in preventing the pollen from germinating, thus making it impossible for the fruit to set; (4) destructive freezes subsequent to the setting of the fruit; (5) probably in some instances excessively high temperatures during the blossoming period, causing interference with the proper setting of the fruit.

The moisture factor.—(1) Excessive rains during the blossoming period, which may wash away the pollen; (2) rains or continuously damp, cloudy weather, which prevent the pollen grains from being properly freed for dissemination; (3) rains that prevent the activity of insects, which bring about the cross-pollination which is necessary with some fruits; (4) excessive droughts, which injure trees or buds; (5) occasional precipitation in such excess as to affect the healthfulness of the trees.

The wind factor.—(1) So strong and continuous during the blossoming period as to prevent the activity of insects upon which pollinization often depends; (2) causing damage to trees or fruit at some period during growth; (3) in its relation to the evaporation of moisture and the serious results which may follow, especially during protracted droughts.

The relative amounts of sunshine and cloudiness and the intensity of the sunshine are also potent factors in their influence upon the behavior of varieties.

This summary admits of extended amplification, but enough has been stated to indicate the complicated nature of the climatic factor in fruit growing. Attention, however, should be directed to the fact that the effect of any one climatic factor may be very greatly modified by other factors that operate simultaneously with it. This fact may be variously illustrated, e. g., the modification of temperature by the wind; the intensified effect of a drought when accompanied by high temperature and a strong wind; the modification of the effect of frost on tender vegetation when followed by a heavy fog, dense clouds, or other conditions which induce a very gradual thawing of the frosted parts.

In sections where the topography is as varied and the ranges in latitude and elevation are as great as they are in the Ozark region, it is obvious that there must be a correspondingly wide range in the climatic conditions. Moreover, a study of climatological data relating to the Ozark region makes it apparent that the storms which reach this portion of the United States vary considerably in their severity in different sections. It is therefore difficult to so analyze the climatic factor in the Ozark region as to adequately and fairly show its full relation to the fruit interests. In general, however, it may be stated that in seasons when the fruit crop is not limited by some climatic factor or factors the varieties that are well adapted to the region may be expected to develop to a very high degree of perfection in size, color, and finish.

While it is true that climatic conditions unfavorable to the production of apples and peaches have occurred rather frequently in some parts of the Ozark region during the past 10 or 12 years, it is also true that the fruit interests in many other sections of the Mississippi, the Missouri, and the Arkansas Valleys, as well as in other regions of the country, have likewise suffered more or less from adverse climatic conditions during the same period.

The decade from 1900 to 1910 represents an important period in the fruit interests of the Ozark region, on account of the great number of trees which came into bearing or which attained an age approaching their full bearing capacity during those years.

The adverse climatic conditions have been largely temperature factors, comprising unseasonably warm periods during the winter, in which the fruit buds have started sufficiently to make them tender, and in this condition they have been injured by subsequent temperatures that were relatively, though frequently not unseasonably, low; frosts that occurred during the blossoming period; and freezes subsequent to the setting of the fruit.

In the earlier days, before fruit growing became a leading industry, an unseasonable frost or freeze might occur and pass almost unnoticed,

although it has been repeatedly stated that the temperature conditions which have damaged the fruit crops in the past 10 years were almost without precedent in earlier years.

The effect of unfavorable temperature conditions upon a fruit crop is often measured by the condition of the orchard. Not infrequently an orchard which has received good care, is thrifty and vigorous, and has fruit buds well developed will pass through a period of adverse temperature conditions with comparatively little injury, when a neglected, depleted orchard will suffer severely. As a result of the experience of some of the apple growers in northwest Arkansas who have given their orchards relatively good care they feel that while adverse temperature conditions may interfere with their success in some seasons they do not prevent the growing of apples with a fair degree of profit.

The "moisture factor," which in some regions is a serious feature, requires no extended discussion in the present case. The annual precipitation averages from 40 to 45 inches. It is usually fairly well distributed, though occasional droughts and periods of excessive rainfall occur; but in these respects conditions are probably as favorable for fruit growing as they are in most other humid regions with which this region may be compared.

In the Ozark region the "wind factor" calls for no particular attention, as it is not generally subject to winds that are serious to the fruit interests.

DATA OF THE MISSOURI PORTION OF THE REGION.

Mr. George Reeder, section director of the United States Weather Bureau, stationed at Columbia, Mo., has contributed a valuable digest of some of the climatological data from several points in Missouri, from which the following quotation is made: ¹

Notwithstanding the supposition that orchards may be more liable to injury from late spring frost at the present time because in many cases almost the entire orchard blossoms at the same time, or to the improved strain of fruit now grown (the latter statement is in much doubt, many authorities claiming that improved fruit is not more sensitive to cold than the varieties grown 30 years ago), the fact remains that the springs of the last 10 years, and particularly the last 5 years averaged colder than those of the preceding 10 or 15 years, and this statement is well supported by climatological data, * * * in apparent substantiation of the popular idea that "our climate has changed." I would, however, earnestly caution the reader not to be too hasty in the conclusion * * * that the climate of Missouri is undergoing a permanent change. Meteorologists of the world generally agree, and the world's climatological records show, that climate is practically unchangeable; that is to say, permanent climatic changes are noticeable, probably, only in geological units of time. On the other hand, the records also indicate that while weather may change from

¹ Reeder, George. "Are the springs colder now?" *Monthly Weather Review*, vol. 38, No. 12, December, 1910, p. 1834. See also "Late spring frosts in relation to the fruit crop of Missouri," in the Fourth Annual Report (fifty-third meeting) of the State Board of Horticulture of Missouri, 1911, pp. 119-131.

day to day or from hour to hour, there are certain changes that move in cycles or oscillations, having uncertain units of time. The cause of these cycles or oscillations is not definitely known, but it has been pointed out by one or two authorities that the wet and cool periods and the dry and warm periods on the earth appear to correspond somewhat with the periods of maximum and minimum sun spots, which in turn are thought to be due to changes in the sun's photosphere. A few students of the subject claim that these weather changes go in cycles of 3 years, then a longer one of about 9 or 11 years, and still a greater cycle of 30 to 35 years, the last being more clearly pronounced; but no general agreement has yet been reached regarding them.

Studies of the mean daily, mean monthly, and mean annual temperatures, while important in themselves, give us a nearly unchangeable factor, and one not particularly interesting or striking in its features. For instance, the variations in the mean annual temperature of Missouri, covering a period of 25 years or more, rarely exceed 3° , and are often less than 1° . It matters not what the extremes may have been during the four seasons, or 12 months, at the close of each 365 days the final value is practically the same year after year. Another example in which the mean temperature gives but little satisfaction as to the variations in the weather that have taken place during a certain period is that for April, 1910, which, for the State of Missouri, differed from its 20-year normal by only 0.3° . Yet the frosts of that month were the most destructive from the viewpoint of the agriculturist and horticulturist, and the weather generally was the most disagreeable from the physiological side that has occurred during, possibly, the past 30 years.

The factor that is the most important, in my opinion, is the daily minimum temperature, which is as a rule nothing more than the lowest night temperature. The night temperatures explain the interesting cause why the crops do not grow and why the season is delayed. The days may be warm and bright, but vegetation as a rule will not flourish as long as the nights continue abnormally cold.

To the above statements regarding the importance of the daily minimum temperature in its relation to plant growth it might also be added that the duration of the minimum temperature, if it is sufficiently low to injure vegetation, is a most important factor. If a critical temperature continues for only a very short time, as sometimes happens, little or no damage may occur, while a longer period of duration may produce disastrous results.

Mr. Reeder further states:

It appears from climatological data * * * that the springs of the past 10 years experienced quite marked temperature departures from the normal. The most interesting as well as the most important question to be answered is, How long will the cold period last? Unfortunately our climatological data do not cover a sufficient length of time to enable us to work out the number of years to each cycle. While the records show periods of both mild and cold springs for the 30 years, the change during the last 20 years from mild springs to unusually cold springs is not only of marked interest to the climatologist but bears rather more serious import to the orchardists, whose earnings have been affected, and who are of course interested in the question of whether mild springs will ever come again.

As we are unable to answer this question positively, and as it is rather more pleasant to be optimistic than pessimistic, we will look to the future springs from the brighter side. It is quite evident that freezing temperatures in May are abnormal for Missouri, especially most of that part south of latitude $39^{\circ} 40' N$. The frost isochronals of the last four years, while unusually late, rather indicate a return to more normal

conditions. While it is possible, of course, the next 10 years may furnish several Mays in which freezing temperatures will occur, the probabilities are that the tendency will be more and more toward the conditions that prevailed from 1894 to 1902, inclusive, which from the record appear to have been highly favorable to the fruit man. Possibly by the close of the decade ending with 1930 the average date of the last killing frost in spring will have receded to where it was, as claimed by the "old-timers," in the eighties—along about April 12.

Doubtless at that period the youth of to-day, then a man of middle age, will be declaiming to all who will listen that "our climate has changed; the springs were colder when I was a boy." "Why," he will continue, "the springs were so cold we had to use mechanical heaters in the orchards during those days to get any fruit at all." And to prove what he says he will point to the old heaters rusting away in the barn.

And thus the pendulum may swing the other way, and again later on swing back to where we are to-day, continuing to swing back and forth for stated periods for centuries to come. Such are the so-called cycles or oscillations of the weather.

In connection with the article by Reeder, data from several representative points relating to spring frosts in Missouri are presented which show that at those points the average date of the last killing frost in the spring during the years 1901 to 1910 was 11 days later than it was during the 10 years preceding 1901.

DATA OF THE ARKANSAS PORTION OF THE REGION.

An examination of climatological data from northwestern Arkansas during the period 1901 to 1910 shows an advance in the average date of last killing spring frost at some points but not all. For instance, the corresponding average date at Fort Smith for the years 1901 to 1908 was eight days earlier than for the period 1891 to 1900. The difference in variation between frost dates at Fort Smith and points farther north may be due to the influence of the Boston Mountains in protecting the portion of the Ozarks south of them from the effects of the cold transcontinental storms which occurred during those years in their transit from west to east. Moreover, many of the orchards in northwestern Arkansas have relatively high locations, with better atmospheric drainage than those where the elevation is the same or nearly the same as the surrounding country.

TRANSPORTATION FACILITIES.

The practicability of growing fruit in a given section is frequently determined by the character and extent of the transportation facilities that are afforded.

In relation to the Ozark region it may be stated that the development of the fruit interests has been largely coincident with the building of railroads, so that in the sections in which commercial orchards exist the railroad facilities are reasonably adequate to the needs so far as the fruit interests are concerned. A large proportion

of the orchards are within a radius of not over 5 miles from some shipping point. There are very few commercial orchards which are not within 10 miles of a railroad station, but large areas in this region are doubtless as well adapted to fruit growing as the sections which have been developed, except that at the present time they are practically inaccessible on account of their distance from railroad facilities. A number of new railroad lines and branches have been constructed within the past few years, thus bringing within the range of possible development for fruit-growing purposes large areas which were previously too remote from railroads to permit of this.

Many of the town and county roads over which it is necessary to haul the fruit, in order to reach a railroad point, leave very much to be desired from the standpoint of good roads. On account of the rugged character of much of this region and the abundance of chert and other rocks, the roads are often very rough. In a great many places they are badly washed and gullied. It should be stated, however, that in and near the towns, as well as in some of the more important rural sections, the roads are, as a rule, fairly good. The crossroads and other less important ones are naturally in worse condition than the average highway that connects points between which there is much travel, but it is also true that much of the fruit must pass over secondary roads.

The "road factor" has a very close and intimate relation to the success of the fruit interests of any region. Its importance is often largely overlooked.

PRESENT POMOLOGICAL STATUS OF THE OZARK REGION.

An extended account of the fruit-growing interests as they now exist in this region is not called for in the present connection, though a few general observations will be of interest to the reader. They will also be of assistance to him as he considers the discussion of varieties which occurs on subsequent pages.

The present extent of the apple and peach interests is indicated under "Introduction." Numerous relatively small orchards have existed in practically all sections of this region for many years, but the extensive commercial development which has occurred during the past 20 or 25 years is generally considered to have had its beginning, at least in southern Missouri, with the planting of the orchards on the Olden Fruit Farm (now the Olden Fruit Co.) at Olden, Mo. In 1885, following the building of the Kansas City, Fort Scott & Memphis branch of the St. Louis & San Francisco Railroad (now operated as a part of the Frisco System), the late Col. J. C. Evans, as the leading spirit of the enterprise, associated with others, made the first plantings on the Olden Fruit Farm, which has

subsequently become one of the most extensive orchards in this entire region. This orchard, however, has not proved a financial success. The planting of commercial orchards at other points in the Ozarks rapidly followed. Probably there were relatively greater orchard interests in northwest Arkansas at the time the Olden Fruit Farm was established than there were in Missouri, though the rapid growth of apple planting in the former section was largely influenced by the building of railroads, which made possible good transportation facilities. The impetus began about 1881 or 1882. The plantings in eastern Oklahoma are more recent, most of the orchards having been set out during the past 12 or 15 years.

Nothing in the whole history of the fruit industry in this country better typifies the American propensity for doing things on a large scale than the size of the orchards in the Ozark region. Comparatively few of the commercial orchards contain less than 40 acres. Orchards of 80 and 160 acres are common, while those containing from 250 to 500 acres are not unusual, and several holdings of even a larger acreage under a single management exist in this region. The planting of such extensive orchards has been unfortunate in many instances. Mistakes in selecting orchard sites, in planting the trees, and in their subsequent management were rather common in the earlier days. Many large orchards were planted by owners who knew nothing about their care and management. Others used all their available funds in buying land and setting out the trees, then were without the necessary capital to properly care for the orchard until it reached a profitable age. While such errors doubtless would be largely avoided in future plantings, as a result of past experience, nevertheless the mistakes made in the older orchards materially affect present conditions.

Other fruits than apples and peaches are also grown here to some extent. Pears, plums, and cherries are produced, though sparingly—probably not enough to supply local demands. Grapes are grown at a few points in considerable quantities. Small fruits, including raspberries, blackberries, dewberries, and strawberries, are grown in some sections—strawberries on an extensive scale. Probably strawberry culture, especially at certain points in southwestern Missouri, and in the northwestern part of Arkansas, where it has become an important commercial fruit, has been more uniformly profitable with a majority of the growers than any other type of fruit culture.

As the writers see the situation, the best interests of the apple and peach industries of some portions of this region will require that the size of the orchards be reduced to such an extent that it will be possible for the owners to give them the requisite attention necessary to maintain them continuously in the best possible condition. When

this is done the orchards will pass through many adverse climatic conditions without serious injury and will therefore be more regularly productive. That successful and profitable orcharding generally throughout the Ozarks may be possible in the future, as it has been at periods in the past, there does not seem to be adequate grounds for doubting. Nevertheless, some sections of the Ozark region appear to be better suited to a type of general farming than to specialization under methods which have prevailed in many instances in fruit growing. Some growers who at one time devoted their entire attention to fruit have already realized this to be a fact and are branching out into other lines of farming.

In this region there is very little stock raising or dairying; conditions seem to be exceptionally favorable for development in either direction. Many kinds of grass, clover, and other crops suitable for forage can be grown in abundance. In regions suited to both, dairying or stock raising and fruit growing make an admirable combination, provided properly arranged systems of crop rotation and farm management are in operation.

With a reduction in the size of the orchards wherever it may seem advisable, as suggested, and the establishment of well-proportioned stock and dairy interests which might be expected with a wisely planned cropping system to furnish a fairly regular source of income, it is believed that the agricultural conditions in general throughout the Ozark region would be greatly improved. With orchards of such size that they could be properly maintained even should there be successive crop failures for several years, the chances are that they would still provide a fairly satisfactory source of income which, though perhaps irregular, would represent a fair annual average.

In any diversified type of farming, however, where fruit growing enters into the combination, there is an almost inherent tendency among the majority of farmers to neglect the orchard if there is conflict between it and other crops that require attention. It is therefore especially pertinent in the present connection to emphasize what has already been said regarding the adjustment of the cropping system so that no serious conflict in the requirements of the several crops shall occur. The reduction in the size of the orchards here suggested is solely with a view to making possible an intensive management of the smaller ones, where it is practically an impossibility so to manage the large ones of the present time. To reduce the size and still continue to neglect them would be to defeat entirely the object of making them smaller, as far as the success of fruit growing is concerned. This may result in the elimination of some crops commonly assumed to be essential to stock raising of any kind. But if close attention to the orchard results in its being profitable as

an orchard, it will be found, frequently, that the necessary feed which can not be grown without neglecting the orchard can be purchased out of the returns of a properly managed orchard and the transaction prove to be a very satisfactory one financially.

Should the size of the orchards be reduced as suggested, it might be desirable, or even necessary, materially to change the present methods of handling the fruit, basing such a change on a system of complete cooperation among the growers as is already being done in some of the best known fruit-growing regions in which the 5-acre or 10-acre orchard is the rule and the larger individual holdings the exception. It is probable that a much closer cooperation among the growers is desirable, and would prove highly advantageous under any conditions which the future may develop.

THE PROBLEM OF VARIETIES.

CONSIDERATIONS GOVERNING SELECTION.

In the development of commercial fruit-growing interests in a new region, the matter of selecting the most suitable varieties for planting is one which must be considered from many different standpoints.

The ultimate object of the commercial fruit grower is to make his business financially profitable. To do this, as far as the matter of varieties is concerned, he must grow those which are reasonably prolific and which are sufficiently well adapted to the climate, soil, and other conditions existing in his region to insure a high degree of perfection in the development of the fruit. Not only this, they must also meet the demands of the market sufficiently well to induce the buyer to pay a satisfactory price for them. A variety may develop to its highest perfection and yet not be profitable to grow commercially because it does not produce enough fruit or because other characteristics that it possesses result in the prices that can be obtained for it at the time it must be offered for sale being insufficient to net a margin of profit to the grower.

It is frequently difficult or even impossible to foretell just how a variety will behave in a region where it has not previously been grown or in a new set of conditions under which it has not been tested. The avoidance of costly mistakes in selecting varieties for a new region is therefore largely dependent upon the knowledge one has of their range of adaptability and of their behavior under conditions which are most nearly comparable with those in the new region.

As applied to the Ozark region, it is probable that a considerable number of varieties have been planted extensively which are not proving as profitable as other sorts which are being grown to only a limited extent. There are still others which at present are but little

known or entirely unknown in this region and which should be thoroughly tested because of their probable value for this region.

There is a sentiment with many of the growers and others that more attention to the culture of summer apples would prove profitable in this region. The demand for such apples has greatly increased in recent years.

The following account of the principal varieties of apples and peaches grown in the Ozark region is offered in the hope that the information may be useful, especially to those who are not familiar with the conditions, in selecting varieties for future planting.

IMPORTANT VARIETIES OF APPLES.

In the following varietal notes an effort is made to state concisely the behavior of each variety mentioned and to give some estimate of its value for the Ozark region. This information, as already stated, is the result of several seasons' study of the conditions and the behavior of the varieties from year to year. The experience of the growers and their opinions and estimates of the different sorts are also taken into account in formulating the summaries that are made.

A remarkably large number of varieties, some of them of much value, have originated in this region. This statement applies particularly to northwestern Arkansas, though seedling varieties of value have appeared in many other sections. Such recognition is given these varieties as space permits.

On account of the large number of varieties which are grown in this region some discrimination is necessary in selecting sorts for discussion. Space limitations forbid reference to all of them. As far as possible the varieties included consist (1) of the sorts which are widely grown, (2) of those now grown only to a limited extent but which appear to be of such value as to warrant more extensive recognition, and (3) certain faulty varieties which are considered likely to be planted without a full knowledge of their tendencies.

Ada Red.

This variety originated about 1890 on a farm located 6 or 7 miles northeast of Springtown, Washington Co., Ark. Its history, as given to the writers in 1907 by Mr. A. G. Philpott, who planted the seed from which the original tree grew, is as follows:

One day, some 18 or 20 years previous, when he was working in a field his daughter brought him two apples, which he ate. They were either Red June or Summer Queen,¹ he is not sure which. One of these apples contained three especially plump seeds, which he planted in a fence corner. The next season these seeds grew and later were grafted to Summer Queen.¹ In grafting, the earth was removed from the crown of the trees and the tops cut off somewhat below the surface. In order to mark the spot where one of these grafted stocks was, Mr. Philpott stuck into the ground beside it one of the tops which he had cut off. This top, which was a mere switch 18 or 20 inches long, formed roots and grew.

¹ The exact identity of the variety referred to as "Summer Queen" is uncertain.

A year or two later when setting out an orchard, Mr. Philpott took up the grafts and with them the "rooted top" and gave them a permanent place in the orchard. Before the latter bore fruit the owner of the place sold it to his niece, Mrs. G. A. Stevenson; the same year, however, it produced its first fruit. It appeared to give promise of value and was then named Ada Red in honor of Mrs. Stevenson's daughter, who bore the name Ada.

It was evidently about 1898 or 1900 that Mr. T. C. Brannon, whose place joins the one on which the original tree stands, became interested in this variety and made about 30 grafts from it. These were the first grafts made from the original tree. Ten or twelve of these Mr. Brannon planted in his orchard, and later he planted 100 or more younger trees of the same variety. It has been propagated only in this local way but has become somewhat widely known in the section in which it originated.

Some of the trees, as well as the fruit characteristics, suggest very strongly the probability of Red June parentage. As the seed from which the original tree grew may have come from an apple of that variety, according to Mr. Philpott's statement, the likelihood of such a parentage is still further strengthened.

The original tree as it appeared July 26, 1907, is shown in Plate II, figure 1. This tree is in a somewhat depleted condition, but the younger trees in Mr. Brannon's orchard show a good degree of vigor and general healthfulness. Some of the younger trees twig-blighted slightly in 1907, but it is claimed that this had not previously occurred. The foliage is generally strong and healthy. (Pl. II, fig. 2.) It is occasionally attacked by some of the leaf-blight fungi, but not more seriously than a great many other sorts.

The original tree has borne annually, at least it has made an attempt to bear every year since it produced its first crop. The older trees in Mr. Brannon's orchard bore their first crop when four years old.

The fruit is described as medium or above in size, roundish; under color yellowish but nearly covered with red and broken stripes of purplish crimson; dots indistinct, small; flesh whitish; texture fine, tender; flavor mild subacid; quality good. In the vicinity of its origin its season is about the middle of August. During the two seasons of 1906 and 1907 the fruit was badly attacked by apple scab where not sprayed, but it is claimed that this has not usually been the case. It is said to be excellent for culinary purposes, becoming soft and pulpy after cooking a very few minutes.

There appears to be a growing demand in the Ozark region for a variety ripening at the season of Ada Red and it is sufficiently promising to warrant thorough testing in all sections of this region.

Akin.¹

This variety is grown in only a few orchards in the Ozark region, but it is considered one of the more promising of the sorts now little known which in recent years have been attracting the attention of fruit growers.

The tree is a strong, very upright grower. The fruit is roundish, slightly ribbed; size, medium; under color yellow, washed over almost the entire surface with bright crimson; flavor mild subacid; quality very good. Season, December to April when held under favorable conditions for keeping.

In this region thus far it has not proved uniformly productive though some of the older trees have borne heavy crops. It is quite probable that trees now 10 to 12 years old which have not as yet set much fruit may become more prolific as they increase in age.

Arkansas. Synonym: *Mammoth Black Twig*.

In the year 1840, or a little later, John Crawford settled at a point in Washington County, Ark., about 2½ miles northeast of what is now Rhea. He brought with him

¹ For a complete history and description of this variety, see Yearbook of the Department of Agriculture for 1903, p. 268.

seeds of the Limbertwig and the *Black Twig*¹ apples. These seeds were planted and from one of them grew the tree which was later named Arkansas, though it is almost universally known among apple growers by its synonym *Mammoth Black Twig*.

According to Mr. G. W. Collins, of Lincoln, Ark., who assisted in making the first grafts of this variety, it was not propagated until 1869. Its fruit was exhibited among other Arkansas varieties and seedlings at the Cotton Centennial Exposition which was held at New Orleans in 1884-85, attracting considerable attention. Since 1885 it has become widely distributed in many sections of the country. In this region it is known to nearly all fruit growers.

The tree is one of the best, making a fine, vigorous, spreading growth, but it is seldom sufficiently productive to render it a profitable commercial apple, even though the fruit has excellent shipping and keeping qualities. The fruit is large, highly colored, and compares favorably in quality with the Winesap and others of that group, but its lack of productiveness is a serious fault. In an occasional season it appears to be more productive throughout this region than in most seasons, and in the same orchard different trees often vary greatly in productiveness in the same year. But a heavily loaded tree is unusual. While there may be some tendency to increase in productiveness as the trees get older, this has not yet become very marked in this region.

On account of the vigor of the tree, checking the growth by root pruning and girdling have been tried in an experimental way in a number of instances with a view to increasing its productiveness. While the results have given some promise, they do not appear to offer a dependable remedy for the fault. For a similar reason, a soil not too rich in nitrogen is probably to be preferred to one which is likely to induce an overabundant growth. While there may be an occasional crop sufficiently large to be profitable to a satisfactory degree, the planting of this variety extensively in this region for commercial purposes does not appear to be warranted at the present time.

The original tree as it appeared in August, 1906, is shown in Plate III, figure 1. A well-pruned 10-year-old tree is shown in figure 2 of the same plate.

The Arkansas has been considerably confused with the Paragon, an apple of Tennessee origin. Though very similar, the two varieties are undoubtedly distinct.

Arkansas Black.

This variety originated on the farm of a Mr. Brathwait, 1½ miles northwest of Bentonville, Ark. It first fruited about 35 years ago. It has become of some importance in a few sections of the country, but it is not popular in the Ozark region. It is known to a large proportion of the growers, but has not been planted extensively. Like the Arkansas, it usually bears only very small crops. Its foliage is often badly attacked by some of the leaf-blight fungi and the fruit is so susceptible to apple scab that it usually becomes entirely worthless unless very thoroughly sprayed. When it is well developed it is a long-keeping apple and has good shipping qualities, but on account of its serious faults it is of very little value in this region under usual methods of culture.

Arkansas Pippin. Synonym: *Mammoth Pippin*.

This variety is known in this region by its synonym rather than as Arkansas Pippin. It is in a comparatively small number of orchards in northwestern Arkansas and southwestern Missouri, but is grown to only a very limited extent. It is a large, light-colored apple, ripening the last of August and early in September. Though it occasionally produces good crops of fairly good fruit, it is not as a rule considered a heavy bearer; neither is it especially prized as a commercial sort. Other varieties of about the same season and well adapted to this region are doubtless more profitable.

Beach. Synonyms: *Lady Pippin*, *Apple of Commerce*.

The original tree of this variety stood on the Oliver Young farm, about one-fourth of a mile west of Bentonville, Ark. It was a small tree of uncertain age during the Civil War; it is known, however, to have produced fruit three years after the war closed.

¹ This variety was probably Winesap, which is known in some sections as *Black Twig*.

Nearly 40 years ago Mr. H. Highfill obtained scions of it from Mr. Young for propagation under the name *Lady Pippin*. From Mr. Highfill's nursery it was distributed more or less in northwestern Arkansas, though it does not appear to have attracted much attention for a considerable period. Some years after it was first propagated, trees of it which had come from the Highfill nursery were found on a place owned by a Mr. Beach. Because of this association, some one named it "Beach," either not knowing that it already bore another name or else in disregard of that fact. More recently it was renamed *Apple of Commerce*.

As the name first given to this variety does not conform to the code of nomenclature of the American Pomological Society, which is quite generally recognized by American pomologists in naming varieties, "Beach" becomes the approved name.

This variety is found in many orchards in northwestern Arkansas, but it is of secondary importance. It is not often found in other sections of the Ozark region. It has been widely advertised in recent years under the synonym *Apple of Commerce*.

The tree grows well and is considered a heavy bearer, but the fruit, though attractive in appearance, has several faulty characteristics. It is rather small, as a rule, and considerably subject to a soft rot and also to bitter-rot. The dessert quality is rather poor. Its chief points of merit are its lateness in reaching maturity for harvesting and its long-keeping qualities.

Baldwin.

Though this variety is the leading commercial winter sort in the northern apple districts from New England westward to Michigan, it is entirely out of its geographical range of adaptability in the Ozark region. It ripens or drops in August or early in September, has a soft texture, and is undesirable in nearly every particular. Fortunately, it is found in only a few orchards.

Ben Davis.

Based on the relative number of trees in the Ozark orchards, the Ben Davis apple is by far the most important variety which is grown in the Ozark region. Probably from 50 to 75 per cent of the entire number of trees in the commercial orchards consist of this variety. This statement, however, does not necessarily indicate its relative value. In fact, there is such diversity of opinion in regard to its actual merits, and considered broadly in its relation to the whole apple industry, the matter is so far-reaching that it is difficult to define the position which it actually holds. Its real position may not be the one commonly ascribed to it.

On the one hand, one grower claims that the Ben Davis is the most profitable variety that he can plant, not because of the high prices for which it sells, but because of the relatively large quantity of fruit which the trees bear—or which he expects them to bear. On the other hand, another grower could not be induced to plant this variety on account of its poor dessert quality and his jealous regard for the reputation for high quality of his fruit on the market.

These two positions represent the two extremes which growers commonly take regarding this variety. It is quite probable that some intermediate position represents more accurately its real value in this region. That there is a place for this variety and others of its group can hardly be denied, though its place should be more clearly defined than at present.

As to the adaptability of this variety to the conditions in the Ozarks, there can be no question concerning its fitness, since in seasons which are favorable to the development of any variety, this one usually reaches a high degree of perfection. During the unusual climatic conditions of the past few years, however, other varieties, especially Jonathan, have borne as regularly.

The rather extravagant claims which are sometimes made regarding the high dessert quality which the Ben Davis develops in this region can not be generally accepted aside from the fact that in texture, juiciness, and in other particulars the fruit from

this region is markedly superior to that grown in a region which is not within the geographical range of the variety.

The tree is generally a vigorous grower, though the foliage is often badly injured by fungous diseases. Bitter-rot and apple blotch are apt to be very serious on the fruit unless thoroughly sprayed. A Ben Davis apple tree, fairly typical for its age in this region, is shown in figure 1.

Great quantities of Ben Davis apples, especially the lower grades, are evaporated in the Ozarks. They make a particularly white stock, attractive in appearance, but



FIG. 1.—A tree of the Ben Davis apple in northwestern Arkansas at the age of 10 years. It is fairly typical of young trees of this variety in the Ozark region.

in dessert quality the evaporated fruit is not better, relatively, than that of the fresh fruit.

Considered in its broad relation to the whole apple industry, the growing of immense quantities of a variety which is recognized as being of such poor dessert quality as is the one in question is a matter which touches every phase of the apple industry. If it were grown and sold only as a cooking apple, the matter would assume a different aspect. In general, it may be stated as a fundamental economic proposition that any commodity of poor quality placed on the market in large quantities for a long period will

ultimately work injury to the enterprise which it represents, however important the enterprise may be.

The Ben Davis apple has repeatedly been placed upon the market in large quantities. At times in many markets scarcely any other sort is to be had in quantity. Its attractive appearance, however, which is widely recognized as the thing which sells it, does not conceal its quality from the purchaser at the time of consumption. He may not know that his last purchase of apples was of the Ben Davis variety, for he does not know varieties; he knows only "red apples," or "yellow apples," or apples possessing some other general characteristic. But he has had these "red" apples often enough to convince himself that he cares very little for apples and is indifferent, at least, as to whether he renews his supply. In a great number of instances, this variety doubtless largely establishes in the mind of the consumer his conception of what apples in general are, and his likes and dislikes, or his indifference, as the case may be, are measured thereby. If by chance he buys from his grocer a supply of some variety of high quality, his impulse is to secure more at once before they are all sold. High dessert quality thus creates a demand for more. At the present time increased consumption of fruit by every legitimate means is one of the most important things for the grower to keep in mind.

The ultimate test of a variety is the attitude of the consumer in regard to it, the prices he can be induced to pay for it after its merits become known, and the demand which it creates.

The "Ben Davis question," however, is important because of the extent to which the variety is grown. In the future development of apple culture in this region this variety as well as the others of its group will probably have a much less important place than it has had up to the present time.

If this course of reasoning is sound, the true position of the Ben Davis variety in relation to the apple industry is apparent and calls for no further argument in the present connection. The grower when reserving a supply of apples for his own use, if he has a general collection of varieties, rarely retains this sort unless it be for use after his other varieties of better dessert or culinary quality are gone. Why, then, should the city consumer who buys his apples by the peck or half peck be expected to esteem it any more highly, relatively, than the grower does?

Many buyers discriminate against the Ben Davis. Frequently they take it only because of the more desirable sorts which can be secured in the orchards in which it occurs. This variety stands for a generalized type of apple culture as opposed to the production of particular varieties, with a view to developing them to a high degree of perfection for a special trade.

Benoni.

Only a few orchards in the Ozarks contain this variety; those in which it has been observed are in southwestern Missouri, where it usually reaches a high degree of perfection and is highly prized in its season.

The fruit is small to medium in size; color yellow, washed with mixed red and broken stripes of crimson; quality very good; season in southwestern Missouri, July, about 10 days to 2 weeks later than Red June.

Though but limited observation of this variety has been possible, it is considered worthy of critical consideration by those who desire an early variety having the size and other characteristics of this one.

Clayton.

This variety is quite generally distributed in this region and occurs in many orchards, though it has not been so extensively planted as many other sorts. Unless the soil is particularly rich and deep and the trees are given good care, they make a rather poor growth and often have a stunted appearance, with strikingly light-colored foliage.

Different trees of this variety have thus far shown considerable irregularity in bearing, even where trees stand side by side in the same orchard. A fair average degree

of productivity is indicated, some trees producing heavy crops and others bearing very lightly. The fruit is frequently borne in large clusters. When this occurs many specimens are small and inferior. Though this variety has thus far been disappointing to some of the growers, where conditions are favorable the fruit develops to a good size, is attractive in appearance, and "good to very good" in dessert quality. It is usually harvested about with the Ben Davis and is said to keep well in cold storage.

In one orchard in 1908, in which the fruit of nearly all varieties was destroyed by severe climatic conditions in the spring, this sort was one of the few that produced a partial crop of fruit.

Where the soil is sufficiently rich and the orchard properly managed, other conditions being favorable, this variety can probably be made of much greater value in the Ozark region than it has been thus far in most cases.

Coffelt.

This variety originated with Mr. Wyatt Coffelt in Benton County, Ark. It has been propagated to some extent, though it has never been extensively planted in this region and apparently is not much esteemed by those who are acquainted with it. In a few instances it has been profitable, but as a rule it is of comparatively little importance. Though of fairly good dessert quality and a good keeper, it is only medium in size and rather dull in color. There is nothing special to commend it for planting, especially as more desirable sorts are available.

Collins. Synonyms: *Collins's Red*, *Champion Red*, *Champion*.

The original tree of this variety is doubtless a chance seedling and stands in a field 5 or 6 miles north or northwest of Lincoln, Washington Co., Ark., on a farm owned (in 1906) by Mr. Samuel Holt. In 1867, Mr. G. W. Collins, of Lincoln, who later became much interested in varieties of local origin, sowed wheat in this field. It was then a small scrubby tree perhaps 1½ or 2 inches in diameter. This tree, as it appeared in August, 1906, is shown in Plate IV, figure 1. A 12-year-old Collins tree is illustrated in figure 2 of the same plate. It has been propagated commercially since about 1886; is planted to a considerable extent in northwestern Arkansas, but not generally grown in other sections of the Ozark region.

The tree is not a particularly vigorous grower, but is usually healthy. It begins fruiting quite young in northwestern Arkansas and is one of the most regular and abundant bearers among commercial varieties.

The fruit is usually not above medium size; but if the trees are not overloaded it is quite uniform and less subject to the common fungous diseases than most varieties. Under favorable conditions it colors highly and keeps well. Its greatest fault is its poor dessert quality. Otherwise, it appears to have much merit for extensive planting in this region.

Etris.

The tree to which the name Etris was first applied stood in the orchard of Mr. A. K. Etris, 5 miles east of Bentonville, Ark. It was obtained about 1873 or 1874 from the Brathwait nursery, located near Bentonville. While it has been claimed that this tree was a seedling, the statement, if true, that another buyer¹ obtained trees of the same variety from the nursery at the same time Mr. Etris obtained his tree, indicates that the one which first received the name Etris could not itself have been a seedling. In tree and fruit characteristics Etris so closely resembles Gano as to suggest a very strong probability of the two sorts being identical.

A few orchards in this region, mostly located in northwestern Arkansas, contain the variety under this name, but its distribution has been quite limited.²

¹ Stinson, J. T. Preliminary Report on Arkansas Seedling Apples. Bulletin 49, Arkansas Agricultural Experiment Station, 1898, p. 11.

² See under "Gano" for a further discussion of varieties of this type.

Florence.

The tree from which this variety was first propagated in this region stood on a farm owned by the late W. E. Buchanan, about 3 miles south or southeast of Bentonville, Ark. This particular tree is generally assumed to be the original one, but as it died several years ago and has since been completely destroyed and the accounts obtainable relative to it are somewhat conflicting, definite historical data are wanting. The statement, however, that it was of considerable size prior to the Civil War appears to be unquestioned.

It is said to have been first propagated commercially about 1891 or 1892 by Mr. J. J. Britt, of Bentonville. It has not been extensively planted, but it appears to possess



FIG. 2.—A tree of the Florence apple in northwestern Arkansas at the age of 14 years; propagated from the original tree. The low head is characteristic of Ozark apple orchards.

much merit for the Ozark region. So far as observed, the largest orchard of it is located on the Buchanan farm already mentioned. This orchard consists of 30 to 35 acres, the oldest trees of which are now about 20 years old. A typical tree is shown in figure 2.

The trees are strong, vigorous growers and thus far appear to be remarkably healthy, with excellent bearing tendencies. The fruit is large, roundish in form, and smooth except for slight undulations of the surface and sometimes more or less ribbing; color, yellow, washed over most of surface with bright mixed red, and splashed with broken stripes of purplish crimson; flesh yellow, medium coarse in texture, breaking, juicy,

subacid, aromatic; quality good to very good. Its season for harvesting is about the middle of August or nearly with Jonathan. It keeps fairly well for an apple of its season, but probably does not hold as well in storage as Jonathan does. On account of the vigor and healthfulness of the tree and the similarity of the fruit in its more general points, some growers have thought that Florence might be grown as a substitute for Jonathan, its preference over that variety being primarily because of the vigor and healthfulness of the tree.

Though not yet grown widely enough for its range of adaptability to have been determined, it has sufficient promise to warrant very careful consideration in future plantings throughout the Ozark region.

Gano.

The history of the Gano apple since this name was first applied to it is a matter of definite record, but the source of the original tree of the variety is uncertain. In a manuscript left by the late Charles Downing there appears, under date of February 4, 1884, a statement which was made to him by Mr. W. G. Gano, for whom this variety was named, as follows: "The Missouri Valley Horticultural Society has named the apple 'Gano.' We found it many years ago in an old orchard with many others we can not name. The orchard was set out some 40 years ago by one Eli Jacks, 4 miles north of Parkville, Platte Co., Mo., planting seedling sprouts. These he grafted old varieties into 10 years after. This tree, however, shows no signs of being grafted, so we conclude that it is a seedling. * * *"

It appears that this "Jacks orchard" was set out in 1844 and came into the possession of Mr. Gano in 1869.¹

Concerning the Mr. Jacks who planted this orchard, it is of interest to note that he formerly lived in Kentucky but emigrated to Howard County, Mo., in the early days, later going to Platte County. It is stated² also that older trees of this variety than those in Platte County are (or were) to be found in an orchard which Mr. Jacks planted in Howard County. Here it was known as "Jacks Red," though this name does not appear to have been published and is now practically obsolete.

This traces the history of the Gano apple to Howard County, Mo., but the source from which Mr. Jacks obtained it is still obscure. He may have brought buds or scions with him from his early home in Kentucky or he might have obtained it elsewhere. According to Mr. Gano³ this variety was first propagated in 1871 or 1872 after it attracted attention in the orchard near Parkville.

Though planted much less extensively than the Ben Davis, the Gano ranks as one of the important commercial varieties in the Ozark region. A young Gano orchard is shown in Plate V, figure 1.

Its range of adaptability appears to be very similar to that of the Ben Davis; its points of merit and its faults are also the same in essential particulars. Being solid red in color, it is preferred to the Ben Davis by some growers and is considered by many to be the more profitable of these two sorts. The texture of the fruit and its dessert quality do not differ materially from the Ben Davis. Commercially, it may be considered a Ben Davis having a solid red color, and the general comments which appear under that variety are also applicable to it, though the apple buyers do not yet discriminate against it as they do against the Ben Davis.

In this connection some comments may be made with propriety regarding several varieties which may be referred to as the "Gano subgroup." Reference is made to Etris, Reagan, Black Ben. or Black Ben Davis and some others less commonly known which resemble Gano so closely that it is impossible to distinguish them with certainty. The history of most of these sorts, if not all, ends in obscurity, as does that of Gano.

¹ Report of the Missouri State Horticultural Society for 1897, p. 355.

² Report of the Missouri State Horticultural Society for 1894, p. 152.

³ Report of the Missouri State Horticultural Society for 1889, p. 181.

In general, the known historical points are about as follows: A tree of an unknown variety is found bearing fruit having mostly Ben Davis characteristics but solid red in color. The name being unknown, one is supplied—in most cases the name of the man who owns the orchard. Perhaps the nursery from which the tree was obtained is known, but if so, nothing further as to its source. The tree may have come from a stock in the nursery which was not budded or grafted, or from one on which the bud or graft failed to grow, or the bud or graft may have come from some Gano tree. No one can say with certainty that it did not. But a new variety, at least a new name, has been added to the list, and confusion has been multiplied because of the close similarity of it to other varieties.

The double origin of varieties, that is, of varieties which appear to be identical in every essential particular, in widely separated places is not new in horticulture. The very close similarity to Gano of authentic Ben Davis seedlings establishes the fact that "double origin," from a practical standpoint at least, in the case of Ben Davis seedlings, may be regarded as somewhat common; and it suggests the possibility, or even probability, that Gano is a Ben Davis seedling. While the other varieties of the Gano type above referred to may or may not have had separate seedling origin, the fact still remains that in essential particulars they are so much like Gano that they may be made to fill commercially about the same place.

Gilpin. Synonyms: *Carthouse*, *Red Romanite*.

This variety is quite widely distributed in the Ozark region, but it is grown only in small quantities. It is found in the older orchards oftener than in those which have been planted in recent years and is usually referred to by one of its synonyms rather than by its correct name.

The tree grows well and in most orchards shows a fairly good producing habit, but the fruit is considerably subject to bitter-rot and other fungous diseases. Its strongest points of merit are its long-keeping qualities and its use for cider; the cider made from it is considered of particularly high quality.

Though fairly good fruit of this variety is produced in this region, it does not appear to be particularly well adapted to the conditions and should probably not be recommended for general planting.

Givens. Synonym: *Arkansas Baptist*.

This variety originated as a chance seedling about 30 or 35 years ago on the farm of Mr. John Givens, located 6 or 7 miles east of Gentry, Benton Co., Ark.

The name *Baptist* or *Arkansas Baptist* was first applied to this variety because of the fact that Mr. Givens was an ardent supporter of that denomination. It was afterwards named Givens and is now seldom referred to by any other name.

It was first propagated by Mr. H. Highfill, of Benton County, and is quite widely distributed in northwestern Arkansas, where it has become of considerable importance. It is not much grown in other sections of the Ozark region.

The tree is a fairly strong, upright grower, with tendency to bear heavy and regular crops. The fruit is medium or above in size, rather highly colored when fully ripe, and its season of maturity is late. It develops in both size and color considerably after most of the other commercial varieties are nearly ready to harvest. Extensive growers who require a long period of time in which to harvest their fruit, usually look upon a succession in the "picking maturity" of their varieties as an important feature. Givens is one of the most satisfactory sorts now being grown in this region with which to extend the picking season. It is not of high dessert quality but better than many other sorts which are much more extensively grown. Though rather subject to bitter-rot, it is doubtless of sufficient value to warrant any attention to spraying that may be necessary in order to control that disease. Some growers consider it one of the best of the newer sorts, and it is probable that it might be grown profitably in this region more extensively than it is at present.

Golden Russet (N. Y.).

Occasionally this variety is found in the older plantings but usually in "family orchards" where only a tree or two of each sort was planted. The tree grows vigorously and bears abundantly and quite regularly in sections which are favorable to apple production. The fruit develops a comparatively high degree of perfection in appearance. Though it may lack somewhat in dessert quality in comparison with fruit of this variety grown in the North, where it would be expected to reach its highest dessert quality, it yet retains much of this quality in the Ozark region. Though it can not be recommended for extensive planting, it may be sufficiently desirable as a late fall variety to be given a place in home orchards, especially in the northern sections of the region.



FIG. 3.—Trees of the Grimes apple in southwestern Missouri at the age of 8 years. The trees are too close together in the row and should be thinned out. The tops of the trees are also too dense.

Grimes. Synonym: *Grimes Golden*.

This variety ranks as one of the important commercial sorts in the Ozarks. In the portion of the region lying between the Missouri and Arkansas Rivers it is widely and extensively grown and is generally considered a profitable variety.

The tree is said to be short-lived here, as in most sections where it is grown, but it makes a rather vigorous healthy growth, without any particular faults. Fairly regular crops are expected, though there is frequently considerable variation in the amount of fruit borne by different trees in the same orchard. It is usually rated as a fairly productive sort. The fruit is borne largely on interior branches of the tree. This distribution of the crop through the tree makes possible the production of heavy loads of fruit without seriously breaking down the branches and avoids also the need of providing means to prevent it. Typical trees of the variety as it grows in the Ozarks are shown in figure 3.

In some instances twig-blight and blossom-blight have been somewhat severe, but, as a rule, these difficulties have not caused serious loss. The fruit, however, appears to be rather susceptible to injury from the curculio, and frequently the loss on account of low-grade fruit caused by curculio stings is considerable, especially in orchards that are not well maintained.

Certain special adaptations have been noted. In one orchard near Neosho, Mo., there has been some indication that it bears better on "prairie soil" than it does on Clarksville stony loam. It is also claimed that the areas of the more extensive soil types in this region which are most highly impregnated with iron oxid are preferable for it than the soils which are less red in color. South of the Arkansas River the Grimes is seldom seen, but in the few instances where it has been observed it does not appear to be as well adapted to the conditions as it does farther north, except at the higher points. The fruit does not develop as well, and the texture and flavor seem to deteriorate. Further observation, however, is necessary to verify these impressions before unqualified statements relative thereto are warranted.

The Grimes apple is usually harvested in the Ozark region during the last of August and early in September and placed at once in cold storage either by the buyers or by the growers themselves if they do not sell the fruit before it is picked.

In future plantings in this region this variety will probably maintain its present position in relative importance. Possibly, as consumers become better acquainted with it and demand a variety of high dessert quality, even if it is not a "red apple," it may be grown profitably in larger quantities than at present.

Hastings Red.

This is a variety of the Gano type; it closely resembles that variety and would doubtless pass for it commercially. As in the case of several varieties of this type, the Hastings Red appeared as a single tree in a block of apples which were all supposed to be Ben Davis. The orchard in which this tree stood was located about half a mile northwest of Gentry, Benton Co., Ark., and belonged to William Hastings. The exact year in which attention was first directed to the tree, on account of the solid pinkish red color of its fruit, is uncertain. Mr. H. Highfill, who propagated it soon after it began bearing, states that it was probably during the years 1870 to 1875. The point of particular interest in connection with this variety appears in Mr. Highfill's experience in propagating it, as related by him in conversation with one of the writers. When the trees which he first propagated from the original one came into bearing, the fruit of about half of them showed a noticeable tendency to stripe similar to the Ben Davis, while the fruit produced by the others was solid pinkish red like the original. He propagated from some of the trees bearing the solid colored fruit and, so far as observed, these have all produced fruit colored like the parent, with no tendency to stripe when fully colored.

As is the case with several varieties of the Gano type, the source of the original tree is unknown and must so remain. The stocks on which were grafted the trees composing the orchard in which the original one stood may have been Ben Davis seedlings, and this particular seedling may have been overlooked in grafting; or the scion may have failed to grow while the stock continued to grow; or it may have been a case of bud variation from Ben Davis. On account of the manner in which the Ben Davis characteristics appeared in fruit from some of the trees which were grafted from the original, the last possibility has some support.

This variety does not at present occupy a prominent place as to commercial importance, though it has been planted in a considerable number of orchards, especially in northwestern Arkansas. As a commercial sort, its value is probably not materially different from Gano, which it closely resembles except in being a somewhat lighter shade of red in color. The claim is sometimes made that it is more juicy and of better

quality than Gano, but if there are any real differences in these particulars they may be regarded as slight. The comments under "Gano" are applicable to this variety.

Highfill.

This variety is a Ben Davis seedling, the seed from which the original tree grew having been planted by Mr. H. Highfill, in 1869, on his place near Springtown, Ark. It has been planted in a considerable number of orchards in the section in which it originated, though not extensively.

The tree makes a fairly good growth, though in some instances the foliage has appeared to be rather weak. A good amount of fruit sets when conditions are reasonably favorable, but close attention to spraying is necessary in order to produce fruit of good grade, as it is quite subject to bitter-rot and apple scab.

The fruit is medium in size, rather firm in texture, and of mild subacid flavor; dessert quality fairly good—considerably better than its Ben Davis parent. In a favorable season it colors very highly and has a heavy purplish bloom. Its season is about with Ben Davis.

Under high culture this variety might perhaps be of considerable commercial value in the Ozarks, but it can not be expected to give a very high degree of satisfaction if grown under neglected conditions.

Holman.¹

This variety appears to be unknown to most Ozark fruit growers. It is said to have originated in Greene County, Mo., 3 miles east of Springfield.

It is interesting to note that this apple was introduced to the Missouri State Horticultural Society as a new variety by the society's committee on nomenclature at the same time that attention was formally directed to the Gano.²

In the Ozark region it has been found in only one orchard, located in Wright County, Mo., where it has been doing fairly well in comparison with the other sorts that are being grown and gives the impression of having sufficient promise to warrant thorough trial throughout this region. The fruit somewhat resembles the Smith Cider apple and is about the same in season as that variety.

Horae.

This variety, probably of North Carolina origin, is not an important commercial variety, yet it is quite widely grown, particularly in the Arkansas portion of this region. When it is handled commercially, the fruit is usually picked during the last of July and early in August. It is often marketed at southern points, particularly in some of the larger towns in Texas, with other early-ripening sorts.

It appears to be well adapted to Ozark conditions and is generally regarded as a profitable variety of its season.

Howard Sweet.

The original tree of this variety is said to have been obtained at about the close of the Civil War from the "Holt nursery,"³ located in the vicinity of Caneyhill, Washington Co., Ark. It was probably a seedling which was planted for stocks but not grafted. The original tree was planted by a Mr. Howard, whose place was located near Cincinnati, Ark. The claim has been made by some that it is identical with Lady Sweet, but it is doubtless distinct. It has been planted considerably, but not widely disseminated, in the section in which it first attracted attention.

It bears good crops of large, highly colored, sweet apples which have a heavy bloom. In dessert quality it rates as good; season, winter.

It is apparently well adapted to Ozark conditions, and is worthy of consideration where a sweet winter apple is desired.

¹ This variety is distinct from one of North Carolina origin bearing the same name, which appears to have attracted some attention in Illinois a good many years ago.

² Thirteenth Annual Report of the State Horticultural Society of Missouri for 1887 (1888), pp. 261-262.

³ For a more extended reference to this nursery see under "Wilson June," (p. 53).

Huntsman. Synonym: *Huntsman's Favorite*.

This variety was brought to notice by a Mr. Whetworth, of Missouri, who refers to it as follows:¹

I brought it into notice in 1843. I found the apple in Johnson County. It was brought from Lexington. I went upon a visit to Cincinnati in 1844 and exhibited it there. They thought much of it and got some grafts. It is the finest apple in the county. A man named Huntsman moved to Missouri; he stopped at old Franklin; a friend gave him some seedlings he had raised; he planted them out, and this was one of them. The trees were 23 or 24 years old when I saw them. Mr. Mock, of Lexington, got them. They keep a long time. They are pale green, turning to a beautiful orange, clear. It was named after Mr. Huntsman, who grew it.

While some of the points in this historical sketch are not entirely clear, especially as to the locations referred to, it fixes the date of the origin as about 1820. It has been quite extensively planted in the commercial orchards of this region, especially in Missouri, and in this respect it ranks as one of the important commercial late fall and winter sorts.

The tree grows well, and it is productive under favorable conditions; but the fruit is very susceptible to bitter-rot and is frequently seriously attacked by apple scab, so that as a rule very close attention to spraying is necessary in order to protect the fruit from these diseases. When properly managed, it develops in this region to a high degree of perfection and is generally considered a desirable variety to grow, but it probably requires higher cultural conditions than most other sorts to bring it to perfection. The fruit is yellow, frequently with a bronzed blush on the exposed side; flesh yellow, subacid, rich; quality good to very good.

Ingram.²

This variety originated on the farm of Mr. Martin Ingram, located about 6 miles northeast of Springfield, Mo., from a seed of the Ralls, which was planted in the doorway about 1850 by his son, John B. Ingram. No particular attention appears to have been given to the original tree until it came to the notice of Mr. D. S. Holman, of Springfield, in 1864, when he found some good, crisp apples in March lying on the ground under this tree. Later Mr. Martin Ingram divided the scions from this tree among three nurserymen, D. S. Holman, J. M. Roundtree, and A. G. McCracken. It was understood that they were to sell the trees at the average price which was being paid for other varieties. The first commercial orchard of this variety was set out near Springfield by Mr. L. K. Haseltine, who now has about 250 acres of it. It has been widely planted in the portion of the Ozark region which lies between the Missouri and Arkansas Rivers.

The tree is very upright in habit of growth while young, but it becomes more spreading as it attains age and as the branches are bent downward by weight of the fruit. It has made a good reputation in this region for productiveness, though under usual cultural conditions it is quite distinctly alternate in its fruiting proclivities. Considerable irregularity in bearing among the trees in the same orchard has frequently been noted. This applies to the size of the fruit as well as to the quantity produced. The tree is generally healthy. A well-grown tree of the variety is shown in figure 4. In a few instances serious blighting of the blossoms has been observed, caused presumably by the same organism that produces twig-blight, but this does not appear to be a frequent occurrence.

The fruit is usually of medium size and "good to very good" in dessert quality. Like the Givens, it is very late in reaching maturity and makes considerable of its growth after most of the other late sorts commonly grown are ripe enough to harvest.

¹ Proceedings of the Missouri State Horticultural Society, 1868, p. 376.

² For a complete history and description of this variety, see Yearbook of the U. S. Department of Agriculture for 1901, p. 382.

It is one of the longest keeping sorts among the commercial varieties growing in the Ozarks and may be held till April and May or even later.

Like its parent, Ralls, it has a late blossoming period, and thereby often escapes late spring frosts and produces fruit when most other earlier blossoming varieties are seriously injured.

Under favorable conditions the Ingram attains a high degree of perfection in this region. The more productive trees, however, are apt to overbear. Doubtless the most profitable and satisfactory method of handling the trees is to maintain them



FIG. 4.—A tree of the Ingram apple in southwestern Missouri, about 12 years of age. This tree shows the upward tendency of the branches, which is very much more marked in trees that have not reached the bearing age. They become more spreading with age and weight of fruit.

under high cultural conditions and to thin the fruit as may be necessary. This course may be expected to keep the trees vigorous and to insure fruit of desirable size.

Properly handled, this variety is undoubtedly of sufficient merit to maintain a prominent place in the apple interests of the Ozark region. In propagating it, however, it seems advisable that scions should be carefully selected from trees which produce fruit of good size and in abundant quantity, in preference to trees that bear small apples.

Jonathan.

Very few varieties are grown more widely in the Ozark region than the Jonathan, and equally few are grown more successfully. Its relative importance is thus indicated. Considered from the standpoint of its intrinsic merits, it is a question if it is not the most valuable sort now being grown in this region in large quantities. This estimate of its value, however, is perhaps not the one which is commonly accorded to it, though it is a popular variety.

The tree is perhaps the weakest feature in regard to the variety. Though it ordinarily makes a fairly strong growth, it is frequently attacked quite severely by twig-blight; less commonly the same disease, presumably, has caused serious blighting



FIG. 5.—A tree of the Jonathan apple in southwestern Missouri, 9 years of age. The rather slender branches which characterize this variety may be noted. Systematic and judicious pruning would improve this tree.

of the blossoms. While blight seldom seriously endangers the life of the tree, its occurrence on Jonathan is frequent in comparison with many other varieties.

In sections where there are many cedar trees and "cedar balls" are abundant, the foliage has proved to be relatively susceptible to cedar rust. The fruit is quite susceptible to bitter-rot, and in unsprayed orchards heavy losses due to this disease often occur. In some places the curculio appears to work on it more than on many other sorts, causing a great many culls and much low-grade fruit. These difficulties, however, appear largely in neglected orchards, the ones maintained under a good system

of management being comparatively free from them. The habit of growth of the Jonathan tree is illustrated in figure 5.

Having some rather serious faults, Jonathan also has many strong points of merit. It is productive and under good cultural conditions quite inclined to bear annual crops. In numerous orchards in this region, during the past 6 or 8 seasons, it has been one of the best varieties to withstand adverse climatic conditions and has frequently borne relatively more fruit than almost any other sort.

While not a large apple, it is of desirable size, especially for dessert purposes, for which it is particularly valuable on account of its high quality. Under favorable conditions in this region, the fruit colors very highly and attains an exceptional degree of perfection. It has been found doing particularly well at certain points in the Ozark region south of the Arkansas River, reaching a rather unusual size. It is always in good demand and brings relatively high prices on the market. Though its normal season in this region is fall and early winter and it must be harvested rather early—that is, during the first half of September (some gather it during the last half of August)—the Ozark-grown fruit behaves well in cold storage if it is well matured when picked and stored very promptly. Its market season usually lasts until about February.

Its value as a storage apple was very clearly demonstrated—perhaps more clearly than it had ever been before—during the Louisiana Purchase Exposition at St. Louis in 1904, where, in the Missouri fruit exhibit, one of the writers examined in August, 1904, specimens of this variety from cold storage which grew the previous season. These specimens did not appear to have deteriorated in any marked degree. The color was brilliant, the flavor excellent, and the texture crisp, firm, and juicy.

The situation in regard to this variety is perhaps well summed up in a statement made to one of the writers by one of the most widely known and extensive orchardists in the Ozark region. This statement was to the effect that had he fully known in earlier years the merits possessed by this variety, half the trees he planted would have been Jonathan instead of Ben Davis.

King David.

This variety originated nearly 20 years ago on the farm of Mr. Ben Frost, located about 3 miles south of Durham, Washington Co., Ark. It has been widely planted in many sections of the country during the past few years. It is found in the Ozarks at present in only a few orchards.

The tree is a good grower so far as observed—usually better than Jonathan, with which this variety in many respects is more nearly comparable than it is with any other. The fruit grown under favorable conditions is medium to large in size; color yellow, washed with mixed red, a few indistinct stripes of dark crimson; flavor subacid, vinous; quality good to very good. Season apparently about with Jonathan.

While the plantings of this variety have not yet reached sufficient age to fully determine its value as a commercial sort, it is considered in general as promising, and if further experience substantiates present indications it will be likely to become an important sort in the Ozarks in the future. The original tree is said to have come into bearing young and to have made a good record for productivity for several years thereafter. Its subsequent record has been subject to the influence of many unfavorable climatic conditions.

Kinnard.¹ Synonym: *Kinnard's Choice*.

This is a variety of the Winesap type which is of much value in some sections of the South; but, judging from its behavior in the few orchards in which it has been found, it

¹ For historical information and detailed description of this variety, see Yearbook of the U. S. Department of Agriculture for 1910, p. 427.

is not well adapted to the section north of the Arkansas River. It is apparently prolific, but the fruit is so susceptible to apple scab that under neglected conditions nearly the entire crop is frequently lost. Probably thorough spraying would control this disease, but, so far as observed, it has shown no characteristics which make it promising except in the southern portion of this region, where the elevations are relatively low. In the South, where it is an important sort, no special tendency to scab has been observed.

Kossuth.

This variety is not widely known to fruit growers; in the Ozark region it is found in only a few orchards.

As far as observed, the tree is a strong and vigorous grower, with foliage comparatively resistant to the common leaf diseases.

Under favorable conditions it is apparently prolific, the fruit not much subject to scab or apple blotch, though sometimes badly attacked by bitter-rot unless adequately sprayed for that disease. The fruit is good size; yellow, striped and splashed with crimson; sweet or very mild subacid, and good to very good in dessert quality. In northwestern Arkansas it should be picked in early September and handled as a fall variety. By some it is considered profitable as an early fall variety. Wherever a variety ripening at this season is desired, it is apparently worthy of wider planting in the Ozark region than heretofore, though its sweet or nearly sweet flavor may be an undesirable characteristic in the estimation of many.

Lawver. Synonym: *Delaware Red Winter*.

This variety is widely distributed throughout nearly the entire country, but is not grown in large quantities. It has been observed in only a small number of orchards in the Ozark region, but in these, as in most orchards elsewhere, it bears so sparingly that it is of little or no commercial value and can not be recommended for general planting. The tree, however, is a strong, spreading, vigorous grower.

Limbertwig.

Many of the older orchards in some sections of this region contain this variety; but it is not grown extensively, and it appears to have no special merit when grown under the usual Ozark conditions. It is susceptible to apple scab and apple blotch, and unless very thoroughly sprayed for these diseases a large proportion of the fruit is frequently lost. Furthermore, it does not appear to be especially well adapted to the conditions in this region, as the fruit seldom develops to a high degree of perfection in comparison with its behavior in some other regions of the country in which it is grown.

When evaporated, the fruit of this variety is not as white, and consequently is less attractive in appearance than many other sorts; but it makes from 1 to 2 pounds more evaporated stock per bushel than most other varieties.

Maiden Blush.

Though not grown in large quantities, this variety is widely distributed throughout the Ozark region and constitutes one of the leading early-ripening sorts. The trees grow well, are not much subject as a rule to disease, and are usually productive to a satisfactory degree, other things being equal. Occasionally there is some twig-blight and blossom-blight, but these difficulties are not often serious. The fruit attains good size for the variety, is relatively free from disease, and develops a rather rich lemon-yellow color, frequently blushing considerably on the exposed side. It ripens in this region during the last half of July and early August. For home use, or for market purposes where an early ripening variety is desired, it is of considerable importance throughout the Ozarks.

McAfee.

This variety has been observed in a few orchards in the Missouri section of the Ozark region. While the tree grows well and the fruit develops to a fairly high degree of

perfection, it is doubtful if it has sufficient merit to recommend it for planting more widely. It is sometimes badly attacked by apple scab, and heavy dropping of the fruit commonly occurs.

Minkler. Synonyms: *Mumper*, *Mumper Vandevere*.

The original tree of this variety appears to have stood in a seedling orchard near Dillsburg, York Co., Pa., which was planted and owned by one John Mumper. This tree is referred to as having been of large size more than 60 years ago.¹ It was apparently introduced into Illinois in the form of scions² as early as the middle of the last century. The Illinois State Horticultural Society recommended it "for further trial" in 1860³ and possibly even at an earlier date.

In Pennsylvania it was known at an early day as *Mumper Vandevere*, though it now appears that this name was not published until 1876.⁴ In Illinois it was tentatively named Minkler, because it was grown by a man of that name (S. G. Minkler), evidently with the expectation that it would at some time be identified as a variety previously named and described.⁵ Because of being the first published, the name Minkler is approved in accordance with the code of nomenclature of the American Pomological Society, even though another name was applied at an earlier date.

This variety is quite widely distributed throughout this region, though it has not been planted extensively. The tree makes a fine, vigorous, healthy growth—one of the best of any of the varieties grown in this region; the fruit attains good size and color and keeps well; but it has produced such very light crops, with almost no exception, that it is practically without value as a commercial sort in the Ozarks.

Missouri. Synonym: *Missouri Pippin*.

There is some conflict of statement regarding the origin of this variety. From the historical account⁶ which appears to be the best authenticated, it originated as a seedling with Mr. Brinkley Hornsby at Kingville, Johnson Co., Mo., about the middle of the last century. This Mr. Hornsby was one of the early settlers in northern Missouri, going to that section from Tennessee. Having a great interest in fruit growing, he brought with him apple seeds from his native State, which he planted at his new home. His first orchard in Missouri was thus composed of seedling trees, the best varieties of which he propagated for distribution. Whenever a graft failed to develop, if the seedling stock on which it was worked grew and manifested promising characteristics, it was Mr. Hornsby's custom to let it remain until it fruited. It appears that the variety now under consideration was one of these stocks on which the graft failed to grow. The tree which developed therefrom fruited for the first time in 1854, but it was not until the crop of 1859 that Mr. Hornsby became satisfied with it. He had intended to name it "Missouri Orange," but finally accepted the suggestion of the late G. C. Brackett and called it *Missouri Pippin*, under which name Mr. Brackett received scions of it from Mr. Hornsby in the spring of 1861. It has become widely known and disseminated under that name.

One of the first, if not the first, published descriptions of this variety was by Warder in his *American Pomology*, under the name *Missouri Keeper*. It appears, however, that it was Warder's intention to adopt *Missouri Pippin* as its name in case he should revise *American Pomology*. Under the code of nomenclature of the American Pomological Society, the name *Missouri Pippin* is reduced to *Missouri*.

This variety has been widely planted in many sections of the country and has frequently been reported to be one of the most profitable of the commercial sorts. It

¹ Letter from Prof. S. B. Heiges, June 15, 1910.

² Letter from Mr. S. G. Minkler, Mar. 27, 1894.

³ Transactions of the Illinois State Horticultural Society, 1860, p. 30.

⁴ Downing, A. J. *The Fruits and Fruit Trees of America*, 2d revision, p. 59 of 2d Appendix.

⁵ Downing, A. J. *Op. cit.*, p. 276.

⁶ Report of the Kansas State Horticultural Society, 1881, p. 209.

has been quite extensively planted throughout the Ozarks, but on the whole it has proved disappointing.

The tree makes an upright, characteristic growth, especially when young and before the rather slender branches become permanently bent down from weight of fruit. The leaves are also very characteristic, being quite long in proportion to the width, dark green, and more glossy than most sorts. These varietal peculiarities make the tree quite easily distinguished from other sorts.

The foliage is often seriously affected by some of the leaf and other fungi, so that unless thoroughly sprayed the trees are often badly defoliated early in the season. The twigs as well as the blossoms are frequently badly attacked by blight. When blossom-blight occurs, it is especially serious, as it prevents the fruit from setting. The tree is rather shallow rooted and the root system is not very abundant in most Ozark soils, so that it is blown over by the wind more often than most other varieties. This is frequently apparent in orchards of mixed varieties in which this one is included. Very early bearing is a characteristic, and on this account it has been in the past widely planted as a "filler." The tendency is toward heavy bearing; in fact, under favorable conditions, it often overbears, and the fruit is very small unless thinned. The fruit is normally not above medium size, highly colored, and with a beautiful finish, so that it is very attractive in appearance when well grown, though it does not rank high in dessert quality. It is very subject to apple scab, apple blotch, and bitter-rot. Unless very thorough spraying is done, heavy losses are apt to occur from these diseases, in some cases practically the entire crop being destroyed.

It will thus be seen that this variety, under Ozark conditions, has many serious faults. On the other hand, the early and abundant bearing of the trees and the attractive appearance of the fruit when well grown have given it considerable popularity in the past, though because of the prevalence and destructiveness of the diseases mentioned in orchards not adequately sprayed, it is not now regarded in this region with as much favor as formerly. In certain other regions of the country it is apparently of greater value than it is in the Ozarks. In still others where it was formerly planted it has been largely dropped in recent years on account of its susceptibility to blight and other diseases.

Northern Spy.

Few orchards contain this variety, though it is occasionally seen in this region. On account of its importance in the older apple districts of the Northern States, it is mentioned in the present connection.

In the Ozarks it is without value, so far as observed. It bears but very little; the fruit rarely holds to the tree until maturity; it rots badly even before ripening, and the specimens that do mature lack the size, color, and flavor which make this sort valuable when grown under conditions to which it is well adapted.

Northwestern. Synonym: *Northwestern Greening.*

In the upper Mississippi Valley, where hardiness of tree with relation to low temperatures is an important matter, this variety is grown quite extensively and with considerable satisfaction. It occurs in only a few orchards in the Ozark region. In the orchards where observed it has proved very unsatisfactory, primarily on account of its susceptibility to the apple-blotch fungus. In unsprayed orchards this disease frequently renders the fruit nearly or entirely worthless, except for evaporating or for cider. Not only is the fruit susceptible to this fungus, but the trees are also sometimes greatly damaged by it—in some cases the twigs, branches, and trunks becoming so injured as to nearly or quite destroy the trees.

While this disease yields to proper spraying, it is doubtful if this variety would prove as satisfactory under Ozark conditions as others of its season. A winter variety in the upper Mississippi Valley, it becomes a fall apple in the Ozarks. While it is inclined to heavy bearing, it would be apt to drop badly even when not attacked by disease.

Oldenburg. Synonym: *Duchess of Oldenburg.*

This is a Russian variety which was introduced into this country through England in 1832 by the Massachusetts Horticultural Society. The fruit was first exhibited as home grown in 1839 by the elder Manning. It is now widely distributed in many sections of the country. The tree is a standard of hardiness where extremely low temperatures are a consideration. It is not extensively grown in the Ozarks, though quite widely distributed. The tree is a moderate grower, not especially subject to disease, and generally desirable in other respects. The limited observations which have been possible indicate that it is generally prolific and regular in bearing in this region when conditions are favorable. The fruit is medium in size; roundish oblate in form; yellow, washed and streaked with red. It is rather sharply acid and of value for cooking rather than for dessert purposes. For its season, which in northwestern Arkansas begins about the middle of July, it is promising for this region. With the increased interest in the growing of early apples and the active market demand for them which has obtained during the past few years, this and other early sorts well adapted to Ozark conditions are worthy of consideration.

Oliver Red. Synonyms: *Oliver, Senator.*

This variety originated in Washington County, Ark., where it has been known for many years. During the past 10 to 15 years it has been more or less disseminated throughout the Ozarks and also in many sections of the country under the name *Senator*, though as a rule it has not been planted heavily by individual growers.

In the section above mentioned, where this variety has been longest known, numerous complaints are made about the tree. In many orchards, for no apparent cause, it presents a rather sickly appearance; the leaves are frequently small and yellowish; branches die and other difficulties appear which suggest lack of constitutional vigor. The foliage is also very susceptible to cedar rust. Some growers attribute this behavior of the tree to insufficient hardiness in the climate of northwestern Arkansas. As trees in the southern extremity of the Ozark uplift, where some of the climatic conditions may be a little milder than they are in northwestern Arkansas, appear to be rather more vigorous in some cases than they are farther north, at least when young, it seems possible that the tree may do better under other climatic conditions than those which prevail in the section where it originated.

Generally, throughout the Ozarks, it is fairly productive; but the trees appear to be quite irregular in this respect, some producing heavily while others bear sparingly. In the localities above referred to, however, where the trees appear to be more thrifty and vigorous, they are not as productive as they are in northwestern Arkansas. Most of these stronger trees that have been observed are under 10 years of age, and it is possible that they may become more productive later.

The fruit is medium to large; under color yellow, washed over nearly entire surface with bright mixed red, and faintly striped with dark crimson; flavor subacid, pleasant, and good to very good in dessert quality. In this region it is a fall apple and is usually picked early in September.

On account of its high quality and beauty of appearance this is a desirable variety where it can be grown successfully. Special methods of culture may be of some value in overcoming the faults that have been mentioned. It is considered worthy of more careful and thorough testing in this and other regions.

Payne. Synonyms: *Payne's Keeper, Payne's Late Keeper.*

This variety was brought to notice by the late J. G. Payne, Everton, Dade Co., Mo., on whose place the original tree stood. The principal points of historical interest connected with this variety, as related to one of the writers by a member of the firm of J. G. Payne Sisters, the business name under which the "Payne place" is now operated, are as follows: The original tree is supposed to have been one of a col-

¹ For more complete historical data see Yearbook of the Department of Agriculture for 1906, p. 357.

lection of seedling trees which grew from seed that was brought from North Carolina, about 1840, by a Mr. Cobla and planted on the Gasconade River, near Rolla, Mo. The season following the one in which these seeds were planted, the seedling trees were removed to the present Payne place near Everton. There were 336 of them. One of these, when it bore, produced very late-keeping apples.

In 1866 J. G. Payne and sisters bought the place on which this seedling apple orchard stood, taking possession the following year. In 1877 some of the apples from this tree which produced late-keeping fruit were exhibited at the meeting of the Missouri State Horticultural Society, held at Springfield, and at that meeting the name *Payne's Late Keeper* was applied to it.

The year following this exhibit, Mr. Payne had 100 trees propagated by John Warren, who was located 5 miles northwest of Springfield. Sixteen of these were given away by Mr. Payne; the others were planted on the Payne place. Fifty-six of these were still living in June, 1910. The original tree died the year following the propagation of this lot.

It has not been widely planted in the Ozark region, though in a small number of orchards it has been given considerable prominence. On the Payne place 226 acres are devoted to it.

The tree is said to be a poor grower in the nursery, but in the orchard it is usually fairly vigorous and satisfactory in habit of growth, frequently holding its foliage well when many sorts are showing much injury from leaf fungi. As a rule it produces regular and abundant crops, though it is rather late, in some cases at least, in coming into bearing. The fruit is less susceptible to the prevalent diseases of this region than a great many varieties are. It is medium and above in size; under color yellow, washed over entire surface with purplish crimson, and thin overspread of gray; flavor sweet, rich, good to very good. In season it is one of the notably long-keeping varieties of this region. Being a sweet apple, it is not likely to become as prominent as would a mildly acid variety having otherwise similar characteristics, since the demand for sweet apples is limited. So far as tested, it appears to be well adapted to Ozark conditions. Where an apple having the qualities possessed by this one is desired, it is worthy of consideration.

Pennsylvania Cider.¹

The exact identity of this variety is uncertain and its history is obscure. It appears to have been grown in Benton County, Ark., under this name for at least 60 or 70 years. The only use of this name, however, that has been made in American pomological literature is as a synonym of Smith Cider, a very different apple. It is stated that the variety in question is also known by some under the name *Pennsylvania Red-streak*. But this name is used by the standard authors on pomological subjects only as a synonym of Wine. As in the case of Smith Cider, Wine is a variety which could not well be confused with the one in question. A Pennsylvania origin for this variety is suggested by its name but thus far it has not been possible to trace it beyond north-western Arkansas, where it is occasionally found and where it has been grown in a few orchards for many years, as above indicated. It may be an old eastern variety, as the name would suggest, which was taken to Arkansas long ago, meanwhile becoming extinct in the East, or practically so, while it has been perpetuated to a limited extent in the Ozark region. Or it may be of local origin and named "Pennsylvania Cider" because of sentiment on the part of some one who became acquainted with it in its early days.

The tree is a fairly good grower, with no characteristics that are especially distinctive. In the few orchards in which it has been observed it is proving moderately productive.

¹ The variety listed as "Babcock No. 13" in Nomenclature of the Apple, Bulletin 56, Bureau of Plant Industry, 1905, is undoubtedly this variety. It appears that the use of Babcock No. 13 as an approved name is erroneous.

Rather high cultural conditions are evidently necessary for the fruit to develop uniformly, since if neglected many of the apples are small and inferior.

The fruit is medium to above in size; surface smooth, except for ribbing in some specimens; color yellow, washed with mixed red splashes and broken stripes of crimson, and covered with rather heavy bloom; flesh yellow, medium fine, breaking, moderately juicy, mild subacid; quality good to very good. As previously stated, this variety is popular with some, especially for home use; others do not regard it as of special importance. It apparently has sufficient merit to warrant more attention than has been given it in recent years.

Balls. Synonyms: *Rawles Janet*, *Geniton*.

This variety is widely distributed throughout the Ozarks, and it is grown in considerable quantities. It is rarely found, however, in the younger orchards. The tree makes a moderately strong, spreading growth and is considered to be long lived as a rule. It is one of the latest varieties to blossom and on this account it sometimes escapes injury from late spring frosts and produces a crop of fruit when most other varieties fail. It often tends to overbear.

The fruit is commonly produced in bunches when the trees bear full, and it is often too small in size to be satisfactory for commercial purposes. It is also exceptionally subject to bitter-rot, apple scab, and other diseases. It is one of the latest varieties to mature and one of the long-keeping sorts. These characteristics would tend to make it a desirable variety, but on account of the defects noted it can not be recommended. It is only under favorable conditions, with high culture and very thorough spraying, that it can be expected to prove at all satisfactory.

Red Astrachan.

While grown at a considerable number of points in the Ozarks, this summer variety is not produced in large quantities. In fact at present it can hardly be considered a commercial variety in this region. The tree makes a good, strong growth and under favorable conditions may be expected to bear well, though it is somewhat inclined to alternate bearing. It does not come into bearing as early as many varieties do.

The fruit reaches good size, and when fully mature it is highly colored. It is too acid in flavor for dessert purposes but is desirable for cooking. Its season of maturity depends, of course, upon the section in which it is grown. In the southern part of the Ozarks it reaches marketable condition the latter part of June or early July. The growers in the Ozarks who have had experience with this variety are in general favorably impressed with it as a summer sort. In some of the other apple regions of the United States where summer apples are grown extensively it is an important variety, though possessing several objectionable characteristics.

Red June. Synonym: *North Carolina Red June*.

Of the summer apples grown in the Ozarks, this is probably one of the most popular varieties; there are but few early sorts that are more widely grown. It is produced commercially in this region to a limited extent.

The tree, though not a particularly strong grower, is generally healthy and thrifty. It begins bearing moderately young and may be expected to produce good crops with regularity under favorable conditions. The fruit is sometimes borne in clusters to some extent, which is an undesirable feature. Its rather small size is its most objectionable characteristic as a commercial apple, but its deep-red color and good quality usually cause it to sell for very satisfactory prices in Kansas City and other comparatively near-by markets. It begins ripening by the middle of June in the southern part of this region and by early July in the more northern sections. It is considered a very profitable variety by some of the Ozark growers.

Rome Beauty.

This variety is widely distributed throughout the Ozark region and occurs in many orchards, but it has rarely been planted in large numbers. The tree reaches fairly

good size, but the foliage is frequently rather weak and subject to leaf diseases, which often cause the leaves to fall prematurely. There are very few places in this region where its record for bearing is satisfactory. It may blossom well and the fruit set abundantly, but in many instances subsequent dropping occurs to such an extent that before the fruit reaches maturity it is nearly all on the ground. This seems to be due simply to a lack of adaptability to conditions, which results in a weak articulation of the stem with the fruit spur. Further, the fruit rarely develops to a satisfactory size, it does not color well, and its general finish is poor. The trees are also tardy in some instances in coming into bearing.

While the above indicates the behavior of this variety, as it has been observed throughout a large part of the Ozarks, there are exceptions which suggest that in some sections under high cultural conditions it may be of value. In the eastern portion of the Ozarks, where the elevation drops below 1,000 feet, it has been found in one or two instances where it was doing much better than in more elevated locations; also at points south of the Arkansas River it is more promising than it is farther north. There is some doubt, however, even in the sections where it appears to be fairly well adapted, whether it would prove of sufficient value for extensive planting. In some of the important apple-producing regions of the country it has become a prominent variety.

Shackleford.

The first tree of this variety is said to have been owned by Judge Shackleford, of Canton, Mo., though it is supposed to have originated in a collection of seedlings grown from seed planted by a Mr. Riley near Athens, Mo. The authenticity of the latter statement, however, has not been verified in the present connection.

It was awarded first prize in 1884 by the Illinois State Horticultural Society. It was introduced about the same time, or possibly a year or so later. It was then anticipated, apparently, that it would soon occupy a very prominent place in the apple interests of the country. Subsequent experience, however, demonstrated that it did not possess qualities requisite to that end. The tree bears early, but the dessert quality of the fruit is very poor. Moreover, in the Ozark region it must be handled as a fall variety and during the autumn numerous other more valuable sorts are available. It is therefore considered of no particular value for this region.

Shannon. *Synonym: Shannon Pippin.*

The origin of this variety is uncertain, but it has frequently been ascribed to Washington County, Ark. It has also been considered by some authorities as identical with Ohio Pippin, a variety of Ohio origin. On the other hand, this identity has been questioned by prominent pomologists.

In some notes left by the late Charles Downing there appear several references giving information which was supplied to him by some of his correspondents in Arkansas. One or two of these references are of particular interest in the present connection and in substance they are as follows:

Richard Thurston, of Van Buren, Ark., in January, 1878, wrote Mr. Downing: "I have been engaged in this section of Arkansas over 30 years in fruit growing and know about the Shannon Pippin. One Granville Shannon, some 35 years ago, bought of a tree peddler and planted at or near a small place in Washington County, Ark., called Evansville, quite a number of apple trees, and when they came into bearing several of the trees bore the apples which, in consequence of having lost the labels and name if any had been attached, took the name of Shannon Pippin."

Another one of Downing's correspondents, John B. Gill, Springfield, Ark., writing in 1884, confirms the above information and gives additional details. He states: "It [the Shannon apple] was brought to Boonsboro, this county, in 1833, by a Mr. Rector, from Indiana, along with a lot of other trees which he brought here for sale, I think from an Ohio nursery, and heeled in at Kidds Mill, 1 mile south of Boonsboro. The Shannon Pippin being small and scrubby, just as they are growing in my nursery

to-day, no one cared to buy them. The labels were finally lost from the trees and Mr. Granville Shannon bought the lot (only 20) at reduced prices and planted them 6 miles south of Boonsboro, where some of the trees at least are growing."

The source of Mr. Gill's information, he further states, was "one J. B. Russell, of Boonsboro, who had operated a nursery almost in sight of Kidds Mill since about the time the trees were brought there."

While the above statements do not necessarily construct a clear historical account of the Shannon apple, they at least suggest what appears to be a reasonable probability as to its origin, so far as it relates to the Ozark region. That the trees referred to above came originally from an Ohio nursery may not be capable of proof, yet these circumstances as recited offer a logical explanation of the manner in which a variety of Ohio origin may have reached Arkansas and there received another name, in case the identity of Shannon and Ohio Pippin is established at any future time.

Apparently, the Shannon was formerly more popular in the Ozark region than it is at the present time. It does not appear, however, to have been planted very much in the Ozarks at any period, except in northwestern Arkansas. In that section it is in a good many of the older orchards. The tree is only moderately vigorous and rather spreading in form. It is said to be rather late in coming into bearing and quite uniformly shy, in the experience of most growers in the section referred to. In fact, this characteristic has doubtless been a large factor in eliminating it from the younger plantings.

The fruit is large; surface very smooth; yellow, occasionally faintly blushed with dull overcast of whitish blotches and streaks; stem very short, often fleshy; flesh yellow, rather coarse, juicy; flavor, mild subacid; quality good;¹ season fall and early winter, though it is often shipped from Arkansas with the late summer varieties before it is fully mature.

In addition to its shyness of bearing, the fruit frequently scabs badly and sometimes rots. On account of its short stem, the growth of the apples produces so much pressure against the limbs on which they are borne that many are forced off, thus causing serious dropping. Though it is said to bring good prices, often in excess of some of the other well-known market varieties, it has too many weak points to make it a profitable apple to grow in this region.

Shockley.

This variety originated in Georgia and is one of the most widely grown sorts throughout the southern apple districts. It is common in the Arkansas and Oklahoma portions of the Ozarks but is seldom found in the Missouri orchards.

The tree is only moderately vigorous; it is upright in habit of growth with rather long, slender branches. There are few varieties that bear more regularly than this one does, though different parts of the tree often alternate, a portion of the limbs producing a heavy crop each season while very little fruit is borne on the remainder of the tree.

The fruit is usually below medium in size, unless very skillfully grown; rather pale yellow, overspread with light red; flesh rather crisp; flavor very mild subacid or nearly sweet; quality only good. It is one of the longest keeping varieties grown in the South. As observed in the Ozarks, however, it is one of the most susceptible of all varieties to cedar rust. The fruit is more often than otherwise severely attacked, while not infrequently a large part of the foliage is lost as early in the season as August as a result of this disease. The fruit is also very susceptible to bitter-rot and apple blotch. To grow the Shockley successfully therefore it must be sprayed with extreme thoroughness.

Its chief value in this region is probably for home use in those sections where cold-storage apples can not be readily obtained and where the supply of fresh fruit for

¹ A detailed description of this variety appears in the Report of the Department of Agriculture (Report of the Pomologist) for 1886, p. 269.

family use during the winter must be held in farm cellars or pits. This statement applies especially to the southern portion of the Ozarks, where the winter varieties of the more northern sections, when grown, lack good keeping qualities.

Smith Cider.

This variety originated in Bucks County, Pa., more than a century ago. It has become widely distributed throughout the country, though in no section has it become of great importance. It is found in many orchards in the Ozark region at widely separated points.

The tree makes a satisfactory growth, though it is inclined to be somewhat scraggy; it may be said to be productive in comparison with other varieties of recognized commercial value. The fruit is medium to large, oblate conic, often somewhat lopsided, though very variable in form and in some other characteristics; color yellowish, striped and splashed with crimson; flesh white, satiny, subacid; quality only good; season late fall and early winter.

Though Smith Cider has some merit for this region, and has proved quite satisfactory and profitable in a few instances where it is grown in commercial quantities, it does not have positive characters sufficient to make it a leading variety. It might be termed "indifferently good" for Ozark conditions. It is only moderately attractive in appearance, only a little better than Ben Davis in quality; moreover, the fruit is sometimes badly attacked by apple blotch.

Springdale.

This variety is another Arkansas seedling. About 1890 it attracted considerable attention in that State and it was predicted that it would eventually become an important sort. It has been more or less disseminated in different sections of the country but has failed to attain the prominence that was anticipated. It has attracted little attention in the Ozark orchards. Probably the fact that it is no better in any particular than a great many other well-known varieties and is inferior to numerous sorts, accounts in a measure for its lack of popularity. The tree makes a good, strong growth but is peculiarly susceptible to the attacks of a disease which produces characteristic knots or tumors on the trunk.¹ The fruit is of medium size or above; color yellow, washed with mixed red and marked with splashes and broken stripes of bright crimson; flesh yellowish, satiny, subacid; quality only good.

Stayman Winesap.

This variety was produced by the late Dr. J. Stayman, of Leavenworth, Kans., from seed selected from a choice collection of Winesap apples. These seeds were planted in 1869.² During the past 12 or 15 years this variety has been widely disseminated in middle latitudes and to a considerable extent on the Pacific coast and throughout the Northwest. Few of the more recently introduced varieties are proving of as great value, both for home use and for commercial purposes, as is this one. In the Ozark region, however, it has been given comparatively little attention, probably on account of the fact that the period of rapid extension of apple culture in this region was largely past before it began to attract much attention from fruit growers.

Trees of Stayman Winesap have been found in the Ozark region in only a very small number of widely separated places. It therefore can not be said to have been tested sufficiently to determine its real value for Ozark conditions.

In one instance the tree appeared to be rather weak; in another case a tree 9 years old had not produced much fruit, though the small quantity it had borne was very pleasing to the owner. As the tree ordinarily is a good, strong grower, bears early,

¹ Apparently the disease described in Circular 3, entitled "Some Stem Tumors or Knots on Apple and Quince Trees," Bureau of Plant Industry, 1908.

² For further historical information and detailed description of this variety, see Yearbook of the U. S. Department of Agriculture for 1902, p. 470.

regularly, and abundantly, the faults noted here are not interpreted as necessarily signifying a lack of adaptability to Ozark conditions.

The fruit is medium to large, averaging considerably larger than Winesap; color yellow, washed with mixed red and marked with splashes and broken stripes of crimson; flesh yellowish, flavor subacid, rich; quality good to very good. The great value of this variety in many different sections of the country, representing a very wide range of conditions in environment, makes it appear probable that it would also be well adapted to the Ozark conditions. Apparently it can be grown with great satisfaction farther north and at higher elevations in the middle latitudes of the United States than the Winesap apple. The Stayman Winesap should be widely tested under Ozark conditions.

Summer Champion.

A remarkably large number of apple varieties have originated in Washington County, Ark., and several of them have become of commercial importance. Summer Champion is one of its contributions. The original tree, now probably 25 years old and possibly older, stands on the farm of Mr. W. T. Waller, located 6 or 8 miles north or northwest of Lincoln. The name "Summer Champion" was applied to it by the owner. It has been grown more or less locally for a good many years, but it is only during the past 8 or 10 years that it has been widely advertised among fruit growers. It is not extensively grown in the Ozarks even at this time, though a small number of orchards contain it in commercial quantities.

The tree is a good, strong, stocky grower, making a rather upright open head. Apparently it bears well when conditions are favorable. The fruit is large; color yellowish white, washed over entire surface with crimson or dark purplish stripes; flesh whitish, satiny, subacid; quality good; season, in northwestern Arkansas, August. It will be noted that it does not rank high in quality; but it is beautifully colored when well matured, and it is regarded by some of the growers in Washington County as one of the best varieties of its season. It is doubtless worthy of careful trial throughout the Ozarks by those who are interested in growing summer apples.

Tull.

Very little appears to be known about this variety. As nearly as its history can be traced, it originated about 1840 near Tull (post office), Grant Co., Ark., from seed planted by the late Abraham Tull. The section of Grant County in which Tull is located was formerly a part of Saline County. In the Ozarks this variety has been found at only a few points south of the Arkansas River (in localities near the place of origin) and in one orchard in southern Missouri. In the former section it is considerably prized as one of the comparatively few good keeping varieties that does well and bears regularly in the long growing seasons which characterize that part of the Ozark region. In southern Missouri trees 10 to 12 years old have not borne very much fruit.

The tree is remarkably thrifty and free from disease. The fruit is of medium size; color yellow, washed with red, a few broken stripes of crimson, sometimes more or less overspread with a "coppery" finish; flesh yellow with green veins; texture fine, tender, juicy; flavor subacid, pleasant; quality good to very good. As above indicated, its season is winter. As far as observed it seems to be largely free from attacks of apple scab, bitter-rot, and other diseases.

While the merits of this variety for planting widely in the Ozarks are largely unknown, present indications point to its probable value, especially for the southern sections having relatively low altitudes.

Wealthy.

It seems rather remarkable that a variety of apple which has been as widely distributed for many years as the Wealthy should not have been planted more commonly

in the Ozarks. As a matter of fact it is in only a very few orchards in this region; these are largely in the southern and in the western or Oklahoma portions. It originated in Minnesota about 50 years ago from seed which is said to have been obtained in Maine.

The trees observed have nearly all been in rather neglected orchards and under these conditions they have been making a rather weak growth. It is not as vigorous as many varieties, even under good cultural methods, and the leaves are characteristically small, often giving the appearance of being somewhat scanty. In some places, especially south of the Arkansas River, the trees have blighted badly. The fruit is medium to large in size unless the trees are very heavily loaded, when it is small; color yellowish white, washed with mixed red or heavily striped and splashed with red when well colored; flesh yellowish white, sometimes tinted red, tender; flavor subacid, sprightly; quality good to very good; season in the southern Ozarks, early August. Probably its time of ripening accounts partially for its not having been planted more extensively in this region in the earlier years. Many apples are now shipped from this region during August in favorable seasons; and with the increasing demand for summer apples it would seem that the Wealthy is worthy of more consideration than has been given to it heretofore. It bears early; this characteristic, together with its rather small growth of tree, renders it a suitable variety to use as a "filler" where the filler system of planting is desired.

• **White Pearmain.** Synonym: *White Winter Pearmain*.

This variety is widely grown throughout the middle latitudes and on the Pacific coast. It is quite widely distributed in the Ozark region. While its importance is only secondary, in comparison with the leading commercial varieties, it is produced in considerable quantities in a few orchards.

The tree makes a rather upright, moderate growth. Its bearing proclivities have been very irregular in this region. In some orchards it tends to overbear and the fruit is undersized, while in others it is reported to bear light crops habitually. This difference in bearing is not readily explained. The fruit is commonly borne in clusters, which necessitates thinning for the best results.

It is of medium size; color pale yellow, commonly with a tinge of red on exposed side; flesh yellowish, flavor subacid, quality good to very good; season winter.

The White Pearmain is much subject to apple scab and frequently is badly attacked by apple blotch and bitter-rot, unless very carefully sprayed. On the other hand, its high dessert quality and other desirable characteristics, especially in the experience of some of the Ozark growers, make it of some value in this region. On account of the special attention required to develop it to a high degree of perfection, however, it is a variety for the expert and the specialist rather than for the general grower.

White Pippin.

Though this variety is widely distributed in many parts of the country, from Maine to the Pacific coast and as far south at least as northwestern Arkansas, it is not produced in important commercial quantities in any section. So far as the fruit indicates, it appears to be one of those "strongly fixed" varieties which do not vary greatly in appearance even when grown under widely different conditions. The fruit is large in size; greenish white to pale yellow when fully ripe, often with pale-crimson blush on exposed side; flesh yellowish white, subacid, rich; quality very good; season winter.

This variety is of so slight importance in the Ozarks at this time that reference to it in the present connection would be unwarranted were it not for the purpose of calling attention to its possible value. The excellent specimens produced under typical Ozark conditions, together with its wide range of adaptability, suggest that it might be made an important variety in this region, especially where high dessert

quality is desired. It should be added that its bearing proclivities have not yet been sufficiently well demonstrated in this region to assure it in this particular. It should therefore be planted cautiously for the present. The fruit is sometimes mistaken for the Yellow Newtown (*Albemarle Pippin*) apple.

Willow. Synonym: *Willowtwig*.

This variety is grown in many widely separated regions of the country. In some of them it has assumed considerable commercial importance. It occurs in many orchards throughout the Ozark region. Though not a leading variety, it is grown in sufficient quantity to be included among the commercial apples of the region.

The tree makes a strong, spreading growth with rather slender, somewhat drooping, willowy branches; hence the synonym *Willowtwig*, by which it is much more commonly known than by its approved name. Under favorable conditions it apparently may be expected to produce abundant crops. The apple is medium to large in size; color yellowish green, washed and striped with dull red; flesh yellowish, flavor mild subacid, quality good; season winter.

Many of the Ozark growers have found this variety especially subject to bitter-rot, and they object to it on this account. In some cases it has been harvested early in September to avoid loss from that disease. However, it is not sufficiently mature for harvesting as early as that, and the color, which at best is apt to be somewhat deficient, is usually very poor at that period. With these defects, therefore, the Willow is not a variety that can be recommended for this region without reservations, though in some cases it has been observed to reach a high degree of perfection for the variety. There are, moreover, some rather strong indications that it is less well adapted to the portion of this region that is south of the Missouri-Arkansas line than it is to southern Missouri.

Wilson June.

This is another one of the many varieties which originated in northwestern Arkansas. The history of the original tree traces back to a period shortly preceding the Civil War and to the Earles Holt nursery, which was located at or near Canehill, Washington Co., Ark. Earles Holt died just prior to the war, and during the war period the nursery existed in what was practically an abandoned condition. Following the close of the war this nursery was cleared up and many of the trees sold. In the spring of 1865 about 1,000 of them were planted by Albert Wilson, then a boy 17 or 18 years of age, and a younger brother, A. J. Wilson, on their father's farm, the "William Wilson" place, located 6 or 7 miles north or slightly northeast of Lincoln, Ark. This farm is still operated by Mr. Albert Wilson, by whom the early history of this variety was supplied in conversation with one of the writers.

These trees were all several years old when planted, as they had been in the nursery since prior to the Civil War. Many of them bore fruit the next year after they were planted on the Wilson place. In 1866 or 1867 one tree in particular attracted special attention. It was the only one of its kind in the orchard. It was about this time that David Moore started a nursery near Lincoln, and he obtained scions of this particular tree, which he propagated. He then named the variety "Wilson June," the apple now under consideration.

To what extent Mr. Moore propagated this variety does not appear. Apparently, however, it was only in a limited way, as it seems to have remained largely unknown even locally until about 1894 or 1895 when it was evidently "rediscovered" on the "Doufit place," about half a mile north of Lincoln, where it then existed as a bearing tree (or trees). At this period Mr. W. M. Norwood began propagating it in his nursery, located 6 or 7 miles northwest of Lincoln. Since he began its dissemination, the variety has locally become quite commonly known, but the "Doufit place" is generally mentioned as the locality of its origin.

More recently it has become widely advertised, but unfortunately it has been confused with another variety, the San Jacinto. Though these two varieties are quite similar in external appearance, the latter is subacid in flavor while Wilson June is sweet when fully ripe.

Just what the source of the original tree was can not now be determined beyond the statement, which appears to be authentic, that it came from the Earles Holt nursery, where it was started prior to the Civil War. It may have been a seedling stock that was grafted and the scion failed to grow or possibly a seedling grown for use as a stock but which was never grafted. That it was of seedling origin in this nursery appears certain beyond reasonable doubt. The characteristics of the fruit strongly suggest that it was of Red June parentage.

The Wilson June tree makes a moderately strong growth, apparently comes into bearing fairly early, and seems to have good bearing proclivities. The fruit is medium to large in size; color yellowish, covered over the entire surface with dark crimson, sometimes indistinct, stripes; flesh yellowish or yellowish white; flavor sweet when fully ripe; quality good to very good; season last of July and early August in north-western Arkansas.

The very attractive appearance and other desirable qualities of this variety commend it rather highly as a summer variety for this region. It is reported to bring good prices on the Kansas City market. Its sweet flavor, however, may make it less generally popular than if its flavor were a mild subacid.

Winesap.

Among the commercial varieties grown in the United States, this one holds a prominent position. Its place of origin is unknown, though it is commonly conceded to have come from New Jersey. The first published description of it appeared in 1817—nearly a century ago. It is widely and quite extensively grown throughout the Ozarks, but with varying degrees of success. In fact, its "performance record" has been such as to make it exceedingly difficult to give a fair and accurate estimate of its real value and adaptability to Ozark conditions. The following discussion may suggest certain general principles which underlie the modification of fruit varieties by environment and their adaptability to different conditions.

The Winesap tree is rather distinctive in manner of growth, the dark green color of the bark and foliage and the drooping limbs being quite characteristic. It makes only a moderately strong growth in this region; the foliage is rather susceptible to diseases of various kinds and twig-blight is not uncommon, though it is rarely very serious.

The fruit is commonly rated as medium in size. Particularly well-grown specimens may be large, though much of the Ozark fruit of this variety is small in size. Its color is yellow, covered nearly entirely with crimson, and marked with a few broken purplish stripes; flesh yellowish or yellowish white; flavor subacid, rich; quality good to very good, being only "good" when poorly grown; season winter.

There appear to be rather well-defined degrees of adaptability of the Winesap apple within the limits of the region under consideration. For the greater part of the Missouri portion and for the part in Arkansas which is north of the Boston Mountains, little can be said in its favor as a commercial apple, at least when grown under the usual cultural methods that largely prevail in these portions of the Ozarks. It is to be found, however, in a very considerable proportion of the orchards.

A general summary of the observations made in regard to it during a period which extends over several seasons may be expressed as follows: Quite inclined to be unproductive, especially in the portions of Missouri and Arkansas above designated; sometimes sets good crops of fruit which nearly all drops; in some cases it holds a full crop, usually of inferior fruit under ordinary cultural conditions; fruit apt to be small and exceedingly scabby; often poorly colored and inferior in every way. Some

seasons the general behavior is more favorable. For instance, field notes for the season of 1906 frequently contain the comment "better this year than usual." Certain other exceptions have also been noted, but in most cases these are in orchards which had received much better care and more thorough spraying than the average. Doubtless, however, its behavior in the "average" orchard is a manifestation of the inherent characteristics of the variety.

In this connection it is of interest to note that south of the Boston Mountains, in the valley of the Arkansas River, where the elevation is relatively low, and continuing to the southern limits of the Ozark region the defects noted above become much less marked. In fact, by some growers in this portion of the region, apparently not without good reason, it is considered one of the best winter varieties they have. On the eastern border of the Ozarks, in southern Missouri, where the elevation drops to about 1,000 feet and below, its behavior is similar to that south of the Boston Mountains, where, in the immediate valley of the Arkansas River, the elevation is only about 500 feet.

It has been repeatedly noted that the fruit of this variety grown at less than 1,000 feet elevation on the eastern border of the Ozarks, in southern Missouri, is strikingly similar in its minute characteristics to typical specimens of this variety as it develops in the Piedmont region of southern Virginia at an elevation of about 1,000 feet, where it attains a high degree of perfection.

Furthermore, its behavior in southwestern Missouri and northwestern Arkansas, as already described, is strikingly similar to its behavior in some of the mountain orchards of Virginia, the elevation of which is considerably above that of the Piedmont region. The similarity of behavior in these two regions is still further brought out in the way it responds to high cultural conditions and thorough spraying. In certain Virginia orchards which are located on sites considerably exceeding 1,000 feet in elevation, where unproductiveness and extreme susceptibility to apple scab were formerly dominant characteristics, it has been made of value by applying better cultural methods and especially by proper attention to spraying. This has also been the experience of some of the Ozark growers.

A most interesting correlation of the Winesap apple in its behavior in the Ozark region and in certain portions of the Piedmont and Blue Ridge regions in Virginia is thus indicated.¹

Summarizing the foregoing discussion, it may be stated that in that portion of the Ozarks north of the Boston Mountains which has an elevation much exceeding 1,000 feet the Winesap apple in the average season may be expected to produce only light crops of fruit, which is usually of low grade on account of scab, small size, and inferior finish—except when thoroughly and properly sprayed and under high cultural conditions. At 1,000 feet elevation and less in southern Missouri and south of the Boston Mountains in Arkansas it appears to be a desirable variety and well adapted to the conditions in those sections. While some of the elevations south of the Arkansas River considerably exceed 1,000 feet, the unfavorable influence of the higher elevations is largely equalized by the more southern latitude of this section.

Yellow Bellflower.

This variety is considerably grown throughout the older apple-producing sections of the North as far west as Michigan, and it is a prominent sort at some points on the Pacific coast, especially in California. It is also more or less widely distributed in other regions, and assumes as much importance in the Ozarks, perhaps, as in any section outside of those designated above. In the Ozark region it forms a secondary variety in many orchards, especially in southern Missouri and in Arkansas north of the

¹ For a rather full discussion of the behavior of the Winesap apple in Virginia, see "Orchard Fruits in the Piedmont and Blue Ridge Region of Virginia and the South Atlantic States," Bulletin 135, Bureau of Plant Industry, 1908, p. 45.

Arkansas River. The tree makes a strong, healthy growth and is not especially subject to disease. The fruit when grown under conditions to which it is well adapted is large, oblong; color yellow, often with blush; flesh yellowish white, tender, crisp; flavor sprightly subacid, aromatic; quality when grown in sections where it is well adapted very good; season winter in the North, but here it is harvested and marketed for immediate use during the last of August and early September. On the Pacific coast it is marketed as soon as it is picked, to some extent for immediate use, but it is also stored for early winter markets.

As grown in the Ozarks, however, the color is usually a pale lemon yellow and the flavor, which is distinctly characteristic in some sections to which the variety is especially well adapted, loses its sprightliness and aromatic qualities and becomes a sharp acid without much distinctive varietal flavor. While it has been quite productive and is considered profitable in a few instances, it produces light crops as a rule and has little to commend it for planting in this region. Both tree and fruit are usually quite free from disease, and in some regions of the country the tree has been found a desirable one to use as a stock for top-working.

Yellow Newtown. Synonym: *Albemarle Pippin*.

This variety, which is especially prominent in certain districts on the Pacific coast and in Virginia in particular locations, occurs in a very few orchards in northwestern Arkansas. It calls for only a brief mention in the present connection. The exacting requirements of this variety in order for it to develop to a high degree of perfection are well known. From such evidence as is available it is apparent that they are not afforded in the Ozark region to a sufficient extent to warrant the planting of it. While the few trees of this variety which have been observed are in a fairly good condition, have made a moderately good growth, and apparently bear considerable fruit in some seasons, it has poor keeping qualities, is small, subject to bitter-rot and other diseases, and does not reach that perfection of "finish" which is particularly essential in this variety.

Yellow Transparent.

Since this variety was introduced from Russia in 1870 by the Department of Agriculture it has become very widely distributed and is now grown more or less in a large proportion of the apple-producing regions of the country. Aside from being a variety which reaches a fairly high degree of perfection under a very wide range of conditions and being of moderately good quality both for cooking and for dessert purposes, its strongest point of popularity doubtless rests upon its earliness of maturity. In fact, were it not for its early date of maturity it is doubtful if it would ever have become generally popular on account of the susceptibility of the tree to blight and the weak growth which it makes except under very favorable conditions. Its season of "market-ripe" condition is the earliest of any widely grown variety, and local sorts are produced which ripen earlier in only a comparatively few sections.

Summer apples do not constitute an important part of the Ozark apple industry at present, and comparatively few growers have the Yellow Transparent in their orchards, though it perhaps occurs as frequently as any other early variety. In a few instances quite heavy plantings have been made.

The tree comes into bearing very early, and for this reason it is often used as a filler between permanent trees. Normally it bears regular and prolific crops. The fruit is medium or above in size; color, beautiful clear yellowish white, often assuming a waxy appearance; subacid; good to very good. Its season in the Ozarks is the middle to the last of June or early July, depending upon the section in which it is grown.

As already stated, the tree generally makes a rather weak growth. This is usual also under Ozark conditions. While in some seasons in this region but very little blight occurs it is very serious other years, destroying not only the twigs but the fruit spurs and even the larger branches in some cases. If it were not for blight this

variety could doubtless be made very profitable in this region under favorable conditions, as the fruit reaches a high degree of perfection; but it is a question if that disease is not too serious a menace to warrant extensive plantings.

York Imperial. Synonym: *Johnson's Fine Winter*.

The origin of this variety traces to York County, Pa. In the course of the development of the apple industry it has become of commercial importance in many sections throughout the country, including the Ozark region. While it is not one of those



FIG. 6.—A tree of the York Imperial apple in northwestern Arkansas, 7 years of age. This tree was selected by the man in charge of the orchard as approximating his ideal for a tree of this variety. The top, however, should be thinned out. A tree of this type is formed by leaving a central "leader" when it is pruned at time of planting and forming the head from the large number of relatively small branches which radiate from the leader. (Compare Pl. V, fig. 2.)

varieties which custom has placed in practically every orchard, at the same time it is in a great many of them. Most of the larger orchards contain it.

The tree makes a good strong growth and is ordinarily quite free from disease, except blight. It is one of the most susceptible to this disease of all the varieties commonly grown in this region. However, rarely more than the twigs of the current season's growth are involved, and the lives of the affected trees are therefore not greatly endangered; but the blighted twigs may be more or less of a menace to other trees in the same vicinity, since they constitute a source of contagion from which the disease may spread. Figure 6 shows a young York Imperial tree.

The fruit when well grown is large in size; color yellow, washed with mixed red, nearly the entire surface being covered in well-colored specimens with a suggestion of striping and overspread of gray; flesh yellow, subacid, good; season winter. As a winter sort, however, it is made less valuable than it would otherwise be by its marked susceptibility to "scald" when in storage. For this reason it is not a satisfactory cold-storage apple. The danger of scald is reduced to a minimum, however, when the fruit is well matured and highly colored at time of picking and is then stored promptly. The quicker the fruit can be cooled after picking to the usual storage temperature for apples the better all varieties will keep, other things being equal.

The value of this variety for Ozark conditions is open to some question. Though it produces good crops of attractive and well-finished apples in some seasons it does not appear to be entirely adapted to this region, at least under the prevailing cultural methods. The trees sometimes set very full of fruit, and thinning is necessary in order to develop to sufficient size; there is some tendency for the fruit to drop unduly; and though the color is fairly good in a favorable season, it is not as high, as a rule, as it is in some other regions where this variety is extensively grown. Moreover, the apples are apt to be very uneven in size, even on the same tree, many being so small that they must be culled out in packing. While this is a common tendency in most regions, it appears to be somewhat intensified in many instances in the Ozark region. This variety, however, probably has greater possibilities for Ozark conditions than has heretofore been realized for it in most of the orchards which contain it. In order to realize these possibilities it should not be allowed to overbear. It should be sprayed systematically with a view to the influence which proper spraying has to prevent the dropping of the fruit; and in many cases better cultural methods aside from spraying are doubtless essential to the production of best results.

IMPORTANT VARIETIES OF PEACHES.

Among the tree fruits grown in the Ozark region the peach holds a place which is second in importance compared with the apple. The census figures given in Table I (p. 7) show the relative importance of these fruits, at least numerically, as they existed in the census years of 1890, 1900, and 1910. While there is a marked concentration of the peach industry at certain points, of which the Koshkonong district in Oregon County, Mo., and the Van Buren-Fort Smith district in Arkansas are notable examples, there is hardly a section in the entire Ozark region where commercial fruit interests have been developed in which they are not grown to some extent. In sections where strawberries are an important commercial fruit they are commonly used as an interplanted crop in young peach orchards, as shown in Plate V, figure 2.

In some respects the variety problem in growing peaches is even greater than it is with apples. In general, it is probably true that most of the well-known peach varieties have a wider range of adaptability than the majority of apple varieties. Though the adaptability factor must be carefully considered, yet the most serious problem in choosing varieties to plant is often more largely in connection with selecting those that mature at particular times than it is in selecting those which reach a good degree of perfection in

any region that may be under consideration. The exact time at which a variety will ripen in a given region frequently determines primarily whether it can be grown profitably there. For instance, in case of the Elberta peach the problem in the further planting of it is not to find localities or regions in which it does well, but rather to select suitable sections for peach culture in which it will ripen at a period when the markets are not already stocked with fruit from other regions.

Again, in the case of the peach specialist who desires to have fruit ripening continuously throughout the "peach season," from early to late, it becomes a critical matter and one of great importance in many ways to select varieties which ripen at such times that he will have no break in the continuity of his harvest. A break in the sequence of ripening may result in more fruit than he can handle with his regular crews at certain times and not enough work to keep them profitably engaged at other periods.

In connection with these investigations 70 or more different varieties of peaches have been reported. Many of these are grown in perhaps but a single orchard, while scarcely a dozen sorts are really of commercial importance in this region. Among the varieties that are produced in considerable quantities the Elberta is relatively of so much greater importance than any of the others that it may almost be said to constitute the peach industry of the Ozarks.

While many of the earlier varieties reach a good degree of perfection in favorable seasons, the prices received for them are not sufficient, as a rule, to render their culture regularly profitable, except to the extent that they may be demanded for local and near-by markets. Prior to the Elberta season in the Ozarks the markets are usually supplied with peaches (largely the Elberta) from other regions in which they ripen earlier than they do here.

By the time the Elberta season is reached in the Ozarks, however, fruit from the earlier ripening districts has largely passed out of the markets, thus making a good demand for the Ozark-grown Elbertas.

The following brief notes regarding the more important sorts will serve to indicate the principal characteristics in their adaptability to this region and their relative value under Ozark conditions.¹ As the Elberta is by far the most important peach variety grown in the Ozark region, the ripening periods of many of the other sorts named in the discussion are given with reference to that variety. (See "Elberta," p. 60.)

An abbreviated description of the varieties discussed is given in Table V (p. 64).

¹ For dates of ripening of the varieties referred to in the following discussion, for which the season is not mentioned, see the respective varietal names in Table VIII (pp. 80 to 86), columns headed "Date first picking" and "Date last picking."

Alexander.

This variety is grown in the Ozark region to a very limited extent, especially at southern points, where it ripens early in June. Its chief value is its earliness. As it does not ship well and is much subject to brown-rot, its usefulness is largely for home consumption; and even for this purpose it can not prove very popular, on account of its inferior dessert quality.

Belle. Synonym: *Belle of Georgia*.

Though this variety is a leading one in the Georgia orchards and is quite widely grown in other sections, it is rarely found in the Ozark region. The few growers who have it in their orchards speak with favor concerning it. In season it slightly precedes the Elberta. At elevations of 1,200 to 1,300 feet in northwestern Arkansas it ripens during the latter part of July.

Carman.

During the past few years this variety has been widely disseminated. As a "second early" sort it is generally giving a good degree of satisfaction, though in some instances it is reported to rot rather badly. This, in general, has been its behavior in the few orchards in this region in which it has been found. At elevations of 1,200 to 1,300 feet in southern Missouri it ripens about the middle of July.

Champion.

This variety is widely grown in many of the northern peach districts, where it is of much value both for home use and for distant markets. It is in quite a good many of the orchards in southern Missouri and a few of the Arkansas orchards. It reaches a high degree of perfection, so far as size, color, etc., are concerned, and is considered of value for local use; but in the experience of a large proportion of the growers who have it the fruit lacks firmness, being too tender to be satisfactory for shipping to distant markets. In this respect there is a marked difference between its behavior in the Ozarks and in the northern districts where it is grown. Apparently its southern limit of adaptability is approached in the latitude of the Ozarks and exceeded so far as important commercial purposes are concerned. Its season is approximately the same as Belle, slightly preceding Elberta. As Belle is a variety of southern origin, while Champion originated in Illinois, it appears probable that the Belle could be satisfactorily substituted in this region for the Champion.

Chinese Cling.

So far as its relative commercial importance is concerned, this variety occupies much the same place in this region that the Champion does. It occurs in a good many orchards, but relatively in very small proportions. The fruit is of good size and has many desirable characteristics, but the experience of most growers in this region shows that it is subject to brown-rot to a serious degree. Its ripening period corresponds quite closely with Elberta, though in some cases it is a few days in advance of that variety.

Early Crawford.

This variety, which has long been a popular sort in many sections of the country, is to be found in this region in only a few orchards, and these are located in widely separated sections. Its general behavior, so far as observed, is rather favorable. The fruit is sometimes inclined to be small, and it has not been as productive in all cases as is desirable. On the other hand, it attains good color and quality and has been less subject to brown-rot than many other sorts. Its season precedes Elberta by a few days.

Elberta.

This is by far the most important peach variety grown in the Ozark region. Concerning its relative importance in southern Missouri, Mr. Paul Evans, Director of the

Missouri State Fruit Experiment Station, states:¹ "In the consideration of commercial varieties, however, we really have but one, the Elberta, and varieties maturing earlier than it are not profitable, except perhaps for small local trade. The Elberta comes more nearly fulfilling all the requirements of a commercial peach than any other variety grown in south Missouri."

In general the above statement applies to the entire Ozark region, as well as to that portion of it referred to in the quotation. It is a question if the above comment relative to the unprofitableness of varieties that ripen earlier than Elberta does not also apply to most of those which are considerably later, though perhaps not for the same reason.

A view of an Elberta peach orchard which has been well cared for, near Van Buren, Ark., is shown in Plate VI.

No extended account of this variety is necessary in the present consideration. Its importance in this region has already been indicated. This suggests in a general way the relatively high degree of perfection which it reaches under favorable conditions. The statements apply to the entire region, though there are doubtless sectional differences in the behavior of the variety which might be noted. Some seasons, especially if there is much rain during the later period of its growth or during the ripening period, heavy losses may occur from brown-rot. The buds are also rather tender and subject to injury by relatively slight extremes of temperature. But these are not regional peculiarities; they are inherent characteristics of the variety. The excellent shipping qualities of the Elberta, which have contributed largely to its great value for commercial purposes in other regions, are usually possessed in a good measure by the Ozark-grown fruit. Moreover, the ripening periods in the different sections of this region are in good sequence with one another and with other regions for the advantageous marketing of the fruit.

Because of the importance of exact ripening periods of this variety in different sections, the dates of first picking in different years at various places in the Ozarks are given in Table IV.

TABLE IV.—*Dates of first picking of the Elberta peach in different years at different places in the Ozark region.*

Place.	Approximate latitude.	Approximate elevation.	1904	1905	1906	1907	1908	1909
ARKANSAS.								
	° /	<i>Feet.</i>						
Magnolia.....	33 15	320			July 10	July 12	July 1	
Horatio.....	33 55	400		July 15	July 13	July 11	July 5	
Corinth.....	34 5	655				July 15	do.	
Grannis.....	34 15	921				July 13	July 7	
Cove.....	34 25	1,300				do.	July 10	
Hot Springs.....	34 30	550					do.	July 10
Mena.....	34 35	1,350	July 20		July 26	July 20		
Hackett.....	35 10	900			July 20	July 15	July 3	
Russellville.....	35 20	1,000				July 25	July 13	July 15
Van Buren.....	35 25	450	July 25	July 20	July 16	July 12	July 15	July 19
Clarksville.....	35 25	450			July 23	July 15	July 10	Do.
Ozark.....	35 30	1,100	July 25		do.	July 23	July 12	July 20
Rudy.....	35 30	800			July 20	July 15	July 15	Do.
Mountsainburg.....	35 40	1,500				July 20	July 20	July 25
Chester.....	35 40	1,900				July 26	July 21	July 29
Lessie.....	35 50	1,600				Aug. 3	July 24	
Springdale.....	36 10	1,400			Aug. 1	July 22	July 20	
Capps.....	36 15	1,440			Aug. 6	July 29	July 16	
Eureka Springs.....	36 20	1,500				July 28	do.	
MISSOURI.								
Seligman.....	36 35	1,650			Aug. 6		July 27	
Koshkonong.....	36 35	911	Aug. 1		July 30	July 28	July 18	
Olden.....	36 50	1,250	Aug. 15		Aug. 7		July 30	
Willow Springs.....	37 0	1,247			Aug. 8		Aug. 3	
Cedar Gap.....	37 5	1,690		Aug. 6	do.		do.	

¹ Peach Industry in South Missouri. Bulletin 12, Missouri State Fruit Experiment Station, 1904, p. 10.

In compiling the above data it was not possible to take into consideration the condition of the various orchards to which they apply. On this account they may not be strictly comparable. At the same time they will perhaps serve a useful purpose, especially as the ripening season of other varieties discussed in the present connection is given in most cases with reference to the Elberta.

The ripening period of this variety in this region also adds to its importance in its relation to the crop in other peach-growing regions. The reason for this exists largely in the fact that in most of the important peach-growing districts, in middle latitudes, in the South, and as far west at least as Colorado (including that State), the Elberta is the leading commercial variety. Its ripening period in the Ozarks occurs, as a rule, when the markets are not oversupplied with peaches from other districts, thus usually insuring good prices. The liberal supplies of Elberta peaches which ordinarily reach the markets from regions where they ripen earlier than in the Ozarks accounts in a large measure for the fact that in this region varieties ripening earlier are less likely to bring satisfactory prices than Elberta.

Emma.

This variety is grown but little in this region. It is much like the Elberta, but about 10 days later. While it is looked upon by some growers as a promising sort for a good market peach to follow the Elberta and is considered very desirable, others report that the buds are very tender and that it does not bear well. In one instance a considerable number of trees in one of the large orchards in southern Missouri were pulled out because they were unprofitable. As these unfavorable impressions were gained from orchards in locations where typical Ozark conditions prevail, it is apparent that this variety should be planted cautiously, if at all, or only experimentally.

Family Favorite.

Of the varieties which ripen prior to the Elberta, this one is relatively of considerable importance. It is contained in a good many orchards, and in some of the larger ones quite heavy plantings of it have been made. It is a white-fleshed peach with fairly firm texture and usually ships well. As a rule it seems to be less subject to brown-rot than many other early and second-early varieties. There are usually four or five days between the last shipments of this variety and the first picking of Elberta. While not always profitable, it has proved satisfactory in many cases.

Heath. Synonyms: *Heath Cling*, *White Heath*.

This variety is one of the most widely planted of the late-ripening sorts. It is grown more or less in most of the peach districts throughout the country. It is not of much importance, however, in the peach industry of the Ozarks, being in only a comparatively few orchards. For a variety ripening four to five weeks after Elberta, it is probably as satisfactory as any for this region. It seems to be rather less subject to peach scab than many of the late sorts.

Late Crawford.

This variety is not an uncommon one in the Ozarks, though it has not been planted extensively. It is frequently reported to bear light crops in this region, and the fruit is often small. It is about a week later than the Elberta.

Mountain Rose.

As a variety to precede the Elberta, in season of ripening, the Mountain Rose is favorably regarded by many of the Ozark growers. It is well adapted to Ozark conditions, reaching a good degree of perfection in favorable seasons. Its high desert quality commends it for home use. To the extent that a peach having the season of Mountain Rose is desired by commercial growers, it is doubtless worthy of consideration.

Oldmixon Free.

The high quality of this variety makes it particularly acceptable for home use where a white-fleshed peach is desired which ripens about with the Elberta. In some seasons it ripens a few days in advance of that variety. Comparatively few of the Ozark orchards contain it, though some of the growers report it as profitable, especially for local markets.

Picquet. Synonym: *Picquet's Late*.

The Picquet is grown more or less in the Ozark region where a late variety is desired. In season it is about with Smock, ripening some three or four weeks after Elberta, that is, about September 1 in southwestern Missouri and northwestern Arkansas. Though it may set a good crop of fruit, it rarely matures well on account of its susceptibility to peach scab. In fact, in the experience of some growers, peach scab has rendered the successful growing of this variety practically impossible. The methods of controlling that disease, however, by the use of certain spray mixtures which have been developed during the past few years may in the future make possible the successful culture of valuable varieties that are extremely susceptible to this disease where heretofore it has been impracticable to grow them.¹

Salway.

This is probably the most extensively planted late variety in the Ozark region. It ripens usually a few days after Smock and Picquet. While its inherent bearing proclivities have doubtless been all that could be desired, its extreme susceptibility to peach scab has frequently greatly damaged or even destroyed the marketability of the crop. Peach scab is a more serious factor with this variety than with even the Picquet, because Salway is much more extensively planted. Were it not for this disease the Salway would apparently be a profitable sort to grow, at least in some portions of this region.²

Slappey.

This variety is regarded by a small number of growers in the Arkansas Valley as a desirable one immediately to precede the Elberta. In the Van Buren section it reaches a good degree of perfection. In appearance it is commonly described as an "early" Elberta, but it is considered by many to be better in dessert quality than the Elberta. It has been observed in the present connection only in the section of the Ozarks mentioned above; hence its desirability for other portions of this region is not definitely known.

Smock.

This variety is in a few of the larger orchards in the Ozarks, but it is of only minor importance. In a general way, the comments under Picquet apply to this variety, though it is probably not as susceptible to peach scab as that variety is. It ripens about with Picquet.

¹ The Control of Peach Brown-Rot and Scab, Bulletin 174, Bureau of Plant Industry, 1910; Spraying Peaches for the Control of Peach Brown-Rot, Scab, and Curculio, Farmers' Bulletin 440, U. S. Dept. of Agriculture, 1911.

² See comments under "Picquet" (*supra*) relative to peach scab.

TABLE V.—*Abbreviated description of important peach varieties.*

[KEY TO ABBREVIATIONS.—*Size:* l, large; m, medium; s, small; v, very. *Color:* b, blushed; c, creamy; g, green; r, red; w, white; y, yellow; s, stained. *Adhesion:* c, cling; f, free; sc, semicling. *Quality:* g, good; p, poor; v, very. A combination of abbreviations is used when it is necessary in order to express properly the characteristics of a variety.]

Variety.	Size.	Color.	Color of flesh.	Adhesion.	Quality.
Alexander.....	m	gw	gws	sc	p
Beile (<i>Belle of Georgia</i>).....	ml	cwb	w	f	g to vg
Carman.....	l	cw	ws	sc	g
Champion.....	ml	gw	w	f	g to vg
Chinese Cling.....	l	cwr	w	c	g to vg
Early Crawford.....	l	yb	ys	f	vg
Elberta.....	l to vl	yb	y	f	g
Emma.....	l	yb	y	f	g
Family Favorite.....	m to l	gw	ws	f to sc	g
Gold Dust.....	m	y	y	c	vg
Greensboro.....	m to l	gw	ws	c	g
Heath (<i>Heath Cling</i>).....	l	wr	gw	c	vg
Late Crawford.....	l	yb	y	f	vg
Lee.....	l	gy	ws	c	g to vg
Lemon Cling.....	m to l	yr	ys	c	vg
Mathews.....	l	y	y	f	vg
Mountain Rose.....	m	wr	ws	f	vg
Oldmixon Free.....	m to l	cwr	gw	f	vg
Picquet.....	l	yb	y	f	vg
Reeves.....	m to l	yr	ry	f	vg
Salway.....	l	yr	y	f	g
Slappey.....	m	yb	ys	f	g to vg
Smock.....	l	y	y	f	g
Victor.....	l	cwb	cw	sc	g
Wonderful.....	l	yb	y	f	vg

The foregoing discussion of varieties with reference to their status in the peach industry of the Ozark region leaves much unsaid that might be added concerning their characteristics. It has seemed unnecessary, however, to carry the discussion further in view of the fact that a single variety—the Elberta—so largely predominates in importance all other sorts. Certain general comments may be added, however, which are pertinent to the variety problem.

Though the later varieties of peaches produced in this region usually bring good prices when they are well grown, the prevalence of peach scab on so many of the late sorts which have been studied has impressed the writers as being a very serious factor in their successful production. In fact, under the usual methods of management that have prevailed in the past, that disease has seemed in many cases to be nearly if not entirely prohibitive of the profitable culture of practically all the late sorts now growing in the principal peach-growing sections of the Ozarks. This statement applies especially to varieties that ripen from about two weeks after the Elberta to the end of the season. However, the recently developed methods of spraying for the control of peach scab, which also include the control of brown-rot, place an entirely different aspect upon the culture of those varieties whose growth heretofore has been impracticable on account of the prevalence of these diseases.¹

¹ See footnote under "Picquet" (p. 63) for references to literature relating to spraying for the control of peach diseases.

The following lists of varieties for local use and for distant market, suggested for certain portions of the Ozarks by persons well qualified to make recommendations relative thereto, are here inserted because of the importance of considering the variety problem from every standpoint.

In these lists for Arkansas and southern Missouri several varieties are mentioned which are not included in the foregoing discussion of peach varieties. The omission in the discussion is due to the fact that though they may be of value they are not yet much grown, and they do not appear to have made any particular impression, except perhaps very locally, upon the peach industry of this region, so far as the writers have been able to observe.

VARIETIES FOR ARKANSAS.¹

For family use or home market: Victor, Greensboro, Carman, Mountain Rose, Family Favorite, Early Crawford, Belle, Champion, Lee (*General Lee*), Emma, Late Crawford, Oldmixon Free, Lemon Cling, Stump, Picquet, Heath, Wonderful.

For shipping: Mountain Rose, Slappey, Elberta, Emma, Mathews (*Mathews Beauty*), Heath (*Heath Cling*), Salway.

These varieties are named in approximately the order in which they ripen.

VARIETIES FOR SOUTHERN MISSOURI.²

For a family orchard: Mountain Rose, Reeves, Reynolds, Early Crawford, Gold Dust, Salway, Heath, Picquet.

For a commercial orchard: Mountain Rose, Reynolds, Elberta, Salway, Picquet.

To the last list might also be added possibly "Evans No. 3," a seedling of Elberta which originated on the Olden Fruit Farm, at Olden, Mo., and which has been grown there for some years. It is virtually a "late" Elberta, ripening about 10 days after that variety. It is considered by some as one of the most promising varieties to follow Elberta in sequence of ripening that has appeared.

PHENOLOGICAL RECORDS.

In previous bulletins of the Bureau of Plant Industry³ coordinate in their subject matter with the present one, varietal records compiled in tabular form from data supplied by cooperative observers have been inserted. These records show the blossoming, picking, and other dates which represent the progress of the development of the different varieties during the season, also dates of last killing spring and earliest fall frosts. The records selected for use relate to the more important varieties grown in the region under discussion and in closely adjacent or contiguous regions.

¹ Walker, Ernest. Peach Growing in Arkansas. Bulletin 79, Arkansas Agricultural Experiment Station, ed. 2, rev., 1909, p. 265.

² Evans, Paul. Peach Industry in South Missouri. Bulletin 12, Missouri State Fruit Experiment Station, 1904, pp. 9-10.

³ Bulletin 135, Orchard Fruits in the Piedmont and Blue Ridge Regions of Virginia and the South Atlantic States; and No. 194, Summer Apples in the Middle Atlantic States.

The same general plan is being followed in the present connection, the object being to give exact information regarding the actual as well as the relative blossoming and ripening periods of a few of the representative varieties of apples and the more important varieties of peaches grown in the Ozarks, the occurrence of frosts, etc.

For such data to have any real significance, however, they must be accompanied by certain information relative to the location, elevation, etc., of the trees from which the records were made. Such information is therefore supplied as fully as limited space permits. In the phenological tables which follow, the approximate latitude and elevation of each place of observation are indicated. The observer is designated in the tables by the number which precedes his name in the "List of observers" given in Table VI. By referring to this list it is possible to ascertain the approximate location at which each record was made.

In Tables VI, VII, and VIII the arrangement is from south to north. That is, the southernmost location is given first, each succeeding entry being a more northerly one, except, of course, where succeeding locations may have the same latitude. It should also be stated that the data as tabulated include records supplied by cooperative observers located at points throughout the States of Missouri, Arkansas, and Oklahoma, and are therefore not restricted in their application to the Ozark region.

TABLE VI.—*List of observers who have furnished the phenological data included in this bulletin.*

Ob- serv- er's No.	Name of observer.	Post office.	County.	State.
1	Mrs. M. A. Birks.....	Fordyce.....	Dallas.....	Arkansas.
2	M. V. Lawson.....	Grannis.....	Polk.....	Do.
3	G. H. Burrows.....	do.....	do.....	Do.
4	J. C. Garland.....	Mona.....	do.....	Do.
5	J. C. Smith.....	do.....	do.....	Do.
6	E. W. Phillips.....	Little Rock.....	Pulaski.....	Do.
7	W. H. Campbell.....	Redoak.....	Lonoke.....	Do.
8	Robert Wheeler.....	Tecumseh.....	Pottawatomie.....	Oklahoma.
9	M. Philips.....	Denver.....	Cleveland.....	Do.
10	J. C. Bauer.....	Judsonia.....	White.....	Arkansas.
11	C. W. Darr.....	Atkins.....	Pope.....	Do.
12	D. M. Thompson.....	Vandale.....	Cross.....	Do.
13	R. Kleiner.....	Wheatland.....	Oklahoma.....	Oklahoma.
14	F. F. Ferguson.....	Union City.....	Canadian.....	Do.
15	Hugo Oberste.....	Hartman.....	Johnson.....	Arkansas.
16	A. W. Poole.....	Ozark.....	Franklin.....	Do.
17	A. S. Perry.....	Yukon.....	Canadian.....	Oklahoma.
18	W. W. Wheeler.....	Salisbury.....	Sequoyah.....	Do.
19	E. K. Creekmore.....	Mulberry.....	Franklin.....	Arkansas.
20	Z. L. Allen.....	Prairie Grove.....	Washington.....	Do.
21	L. C. Fouquet.....	Chandler.....	Lincoln.....	Oklahoma.
22	J. C. Jamison.....	Guthrie.....	Logan.....	Do.
23	J. W. Hann.....	Westfork.....	Washington.....	Arkansas.
24	E. A. Bullington.....	Lincoln.....	do.....	Do.
25	J. F. Bain.....	do.....	do.....	Do.
26	Arkansas Agricultural Ex- periment Station.	Fayetteville.....	do.....	Do.
27	J. M. Rice.....	Winnview.....	Blaine.....	Oklahoma.
28	D. N. Leerskov.....	Tahlequah.....	Cherokee.....	Do.
29	F. W. Ellis.....	Fayetteville.....	Washington.....	Arkansas.
30	Oklahoma Agricultural Experiment Station.	Stillwater.....	Payne.....	Oklahoma.
31	J. J. Boughton.....	Shafter.....	do.....	Do.

TABLE VI.—List of observers who have furnished the phenological data included in this bulletin—Continued.

Ob- serv- er's No.	Name of observer.	Post office.	County.	State.
32	Dr. A. C. Smith.....	Springdale.....	Washington.....	Arkansas.
33	W. J. Patton.....	do.....	do.....	Do.
34	A. M. Kennon.....	do.....	do.....	Do.
35	T. M. Meigs.....	Siloam Springs.....	Benton.....	Do.
36	Robert H. Carl.....	Gentry.....	do.....	Do.
37	J. B. Furrow.....	do.....	do.....	Do.
38	Ozark Orchard Co.....	do.....	do.....	Do.
39	R. J. Maxon.....	do.....	do.....	Do.
40	S. C. Hart.....	do.....	do.....	Do.
41	D. T. Michenor.....	Capps.....	Boone.....	Do.
42	Sherman Ackley.....	Keystone.....	Pawnee.....	Oklahoma.
43	J. M. Taylor.....	do.....	do.....	Do.
44	L. J. Gibson.....	Dixie.....	do.....	Do.
45	J. A. Douglas.....	Perry.....	Noble.....	Do.
46	H. H. Cummlins.....	Bernardi.....	Major.....	Do.
47	Carl A. Starck.....	Monte Ne.....	Benton.....	Arkansas.
48	W. P. George.....	Berryville.....	Carroll.....	Do.
49	J. Stiles.....	Eureka Springs.....	do.....	Do.
50	B. F. Putnam.....	do.....	do.....	Do.
51	J. Goldenberg.....	do.....	do.....	Do.
52	C. R. Burnett.....	do.....	do.....	Do.
53	R. Dixon.....	do.....	do.....	Do.
54	W. H. Hopkins.....	do.....	do.....	Do.
55	I. B. Lawton.....	Bentonville.....	Benton.....	Do.
56	D. S. Helvern.....	Mammoth Spring.....	Fulton.....	Do.
57	W. I. Patterson.....	Rogers.....	Benton.....	Do.
58	J. W. McCracken.....	Sulphur Springs.....	do.....	Do.
59	J. D. Yost.....	Ketchum.....	Mayes.....	Oklahoma.
60	John Coleman.....	Aline.....	Alfalfa.....	Do.
61	Ozark Orchard Co.....	Lanagan.....	McDonald.....	Missouri.
62	B. Beaver.....	do.....	do.....	Do.
63	Ozark Orchard Co.....	Goodman.....	do.....	Do.
64	W. C. Paynter.....	Koshkonong.....	Oregon.....	Do.
65	L. G. Sessen.....	West Plains.....	Howell.....	Do.
66	J. F. Christian.....	Purdy.....	Barry.....	Do.
67	Enoch Brown.....	Willow Springs.....	Howell.....	Do.
68	Thomas Brownlee.....	do.....	do.....	Do.
69	M. E. Broadbush.....	Seymour.....	Webster.....	Do.
70	E. E. White.....	do.....	do.....	Do.
71	W. T. Flournoy.....	Marionville.....	Lawrence.....	Do.
72	E. C. Cowles.....	do.....	do.....	Do.
73	J. B. Wild & Bros.....	Sarcxie.....	Jasper.....	Do.
74	H. Crofoot.....	Chilocco.....	Kay.....	Oklahoma.
75	B. C. Auten.....	Carthage.....	Jasper.....	Missouri.
76	G. T. Tippin.....	Nichols.....	Greene.....	Do.
77	J. H. Purrinton.....	Elwood.....	do.....	Do.
78	W. M. Carr.....	Oakside.....	Shannon.....	Do.
79	S. I. Haseltine.....	Springfield.....	Greene.....	Do.
80	P. V. Carvey.....	Lutesville.....	Bollinger.....	Do.
81	W. H. Litson.....	Nevada.....	Vernon.....	Do.
82	J. C. Evans.....	Richland.....	Pulaski.....	Do.
83	R. J. W. Bloom.....	do.....	do.....	Do.
84	W. D. Gibson.....	Dixon.....	do.....	Do.
85	M. S. Barnett.....	Cuba.....	Crawford.....	Do.
86	L. D. Grover.....	do.....	do.....	Do.
87	H. R. Anderson.....	Jake Prairie.....	do.....	Do.
88	J. W. McCormick.....	Coffeyton.....	do.....	Do.
89	Mrs. L. E. Hastings.....	Dell.....	Benton.....	Do.
90	R. C. Tune.....	Amoret.....	Bates.....	Do.
91	M. L. Bonham.....	Clinton.....	Henry.....	Do.
92	J. C. Ruder.....	Afton.....	St. Louis.....	Do.
93	A. J. Davis.....	Jefferson City.....	Cole.....	Do.
94	H. Wm. Thies.....	Ferguson.....	St. Louis.....	Do.
95	Simon Moser.....	O'Fallon.....	St. Charles.....	Do.
96	C. H. Dutcher.....	Warrensburg.....	Johnson.....	Do.
97	Missouri Agricultural Ex- periment Station.	Columbia.....	Boone.....	Do.
98	W. C. Fourt.....	Fulton.....	Callaway.....	Do.
99	J. H. Darche.....	Parkville.....	Platte.....	Do.
100	H. B. McAfee.....	do.....	do.....	Do.
101	A. L. Norton.....	Clarksville.....	Pike.....	Do.
102	E. Hines.....	Carrollton.....	Carroll.....	Do.
103	F. W. Forward.....	Prairie Hill.....	Randolph.....	Do.
104	G. C. Cole.....	Center.....	Ralls.....	Do.
105	H. A. Squires.....	Dearborn.....	Buchanan.....	Do.
106	L. H. Fisher.....	Reger.....	Sullivan.....	Do.
107	J. W. Turner.....	Albany.....	Gentry.....	Do.
108	Wm. H. Dowell.....	Granger.....	Scotland.....	Do.
109	E. N. Monroe.....	Unionville.....	Putnam.....	Do.

TABLE VII.—*Phenological records of apples.*

BEN DAVIS.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
1	Arkansas	33 45	400	Level.	Sandy clay.	1905	Yr.	Mar. 25	Mar. 31	Mar. 21		Aug. —	Nov. 10		
4	do	34 30	1,250	E.	Sandy loam.	1907	10	Mar. 20	Mar. 28	Apr. 5		Sept. 1	do	Oct. 1	Apr.
6	do	34 30	1,350	S. E.	do	1907	10	Mar. 20	Mar. 28	Apr. 5		Sept. 1	do	Oct. 1	Apr.
7	do	35 0	287	S.	do	1903	12	Apr. 12	Apr. 9	Apr. 24		Oct. 21	Oct. 21		
8	Oklahoma	35 15	1,026	S.	Clay loam.	1905	3	Apr. 12	Apr. 18	Mar. 20		Oct. 30	Oct. 16	Oct.	
8	do	35 15	1,026	S.	do	1906	4	Apr. 5	Mar. 20	Mar. 28		Oct. 30	Oct. 16	Oct.	
9	do	35 15	1,200	W.	Sandy loam.	1905	9	Apr. 5	Mar. 20	Mar. 28		Oct. 30	Oct. 16	Oct.	
12	Arkansas	35 15	260	S. E.	do	1904	10	Mar. 24	Mar. 21	Apr. 4		Sept. 20	Nov. 23	Sept. 15	Dec.
13	Oklahoma	35 15	1,250	N. E.	do	1906	14	Apr. 10	Mar. 20	Apr. 20		Sept. 15	Nov. 8	Sept. 15	Mar.
13	do	35 15	1,250	N. E.	do	1907	15	Apr. 20	Apr. 13	Apr. 1		Sept. 10	Nov. 26	Dec.	Spring.
16	Arkansas	35 30	1,100	W. E.	do	1902	20	Apr. 23	Apr. 5	Apr. 20		do	Nov. 17	Nov. 1	Mar.
16	do	35 30	1,100	W. E.	do	1903	21	Mar. 23	Apr. 4	Mar. 30		do	Nov. 28	Dec.	Feb.
16	do	35 30	1,100	W. E.	do	1905	23	Mar. 23	Apr. 4	Mar. 30		do	Nov. 28	Dec.	Do.
16	do	35 30	1,100	W. E.	do	1906	24	Mar. 24	Apr. 10	Mar. 20		do	Nov. 13	Nov.	Do.
16	do	35 30	1,100	W. E.	do	1907	25	Mar. 18	Feb. 3	Mar. 15		do	Nov. 11	Oct.	Apr.
17	Oklahoma	35 30	1,250	N.	do	1904	12	Apr. 1	Mar. 26	Mar. 20		Oct. 1	Nov. 9	Sept.	Dec.
19	Arkansas	35 30	704	S.	do	1903	11	Apr. 8	Apr. 16	Apr. 1		do	Nov. 17	Oct. 15	Do.
21	Oklahoma	35 45	1,000	N. W.	do	1907	15	Apr. 22	Apr. 12	Apr. 1		Aug. 1	Nov. 11	Oct. 15	Do.
21	do	35 45	1,000	N. W.	do	1908	16	Apr. 22	Apr. 12	Apr. 1		Aug. 1	Nov. 11	Oct. 15	Do.
22	do	35 45	992	S.	do	1904	9	Apr. 2	Apr. 19	Apr. 10		Oct. 12	Oct. 26		
22	do	35 45	992	S.	do	1905	10	Apr. 2	Apr. 26	Apr. 24		Oct. 3	Nov. 11	Oct. 20	Dec.
23	Arkansas	36 0	1,850	Level.	Clay loam.	1905	7	Apr. 11	Apr. 8	Apr. 21		Oct. 3	Nov. 31	Sept. 30	Nov.
23	do	36 0	1,850	Level.	do	1906	8	Apr. 12	Early	Apr. 17		Oct. 3	Nov. 31	Sept. 30	Nov.
23	do	36 0	1,850	Level.	do	1907	9	Apr. 12	Early	Apr. 17		Oct. 3	Nov. 31	Sept. 30	Nov.
23	do	36 0	1,850	Level.	do	1908	10	Apr. 12	Early	Apr. 17		Oct. 3	Nov. 31	Sept. 30	Nov.
24	do	36 0	1,480	E. S.	Sandy loam.	1907	10	Mar. 23	Mar. 24	Apr. 17		Oct. 5	Nov. 11	Oct. 10	Jan.
24	do	36 0	1,480	E. S.	do	1908	9	Mar. 23	Mar. 26	Apr. 17		Oct. 5	Nov. 11	Oct. 10	Mar.
25	do	36 0	1,400	N. W.	do	1905	8	Apr. 1	Apr. 25	Apr. 10		Nov. 1	Nov. 1	Nov. 1	Do.
26	Oklahoma	36 0	900	Level.	do	1907	8	Mar. 25	Feb. 10	Mar. 10		Nov. 1	Nov. 1	Nov. 1	Do.
32	Arkansas	36 15	1,350	Level.	Clay loam.	1904	8	Mar. 25	Apr. 7	Apr. 15		Sept. 25	Oct. 20	Dec.	Jan.
32	do	36 15	1,350	Level.	do	1905	9	Mar. 25	Apr. 7	Apr. 15		Sept. 25	Oct. 20	Dec.	Jan.
32	do	36 15	1,350	Level.	do	1906	10	Apr. 4	Mar. 12	Apr. 12		Sept. 25	Oct. 20	Dec.	Jan.
33	do	36 15	1,300	W.	do	1902	14	do	Mar. 23	Apr. 10		Sept. 15	Oct. 10	Sept. 1	Apr.
34	do	36 15	1,400	S.	Clay	1906	15	do	May 14	July 28		Oct. 10	Nov. 10	Dec.	May
34	do	36 15	1,400	S.	do	1907	16	Apr. 20	May 15	July 28		Oct. 10	Nov. 10	Dec.	May
35	do	36 15	1,200	S.	Clay loam.	1907	20	Mar. 19	May 15	July 28		Oct. 10	Nov. 10	Dec.	May
35	do	36 15	1,200	S.	do	1908	21	Mar. 19	May 15	July 28		Oct. 10	Nov. 10	Dec.	May
36	do	36 15	1,237	S.	Gravelly clay.	1907	18	Mar. 23	Apr. 6	Apr. 28		Oct. 1	Oct. 13	Sept. 1	Spring.
36	do	36 15	1,250	S.	Sandy loam.	1904	8	Apr. 6	Apr. 25	Apr. 28		Oct. 1	Oct. 13	Sept. 1	Spring.
38	do	36 15	1,250	S.	do	1906	9	Apr. 3	May 11	June —		Sept. —	Oct. 10	Oct. 10	Spring.

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TABLE VII.—*Phenological records of apples*—Continued.

BEN DAVIS—Continued.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date of first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
82	Missouri	38 0	Feet.	SE.	Clay	1905	Yrs.	Apr. 20	Apr. 28	Apr. 24	Apr. 25	June 20	Oct. 10	Oct. 12	Aug. 1	May.
82	do.	38 0	1,450	SE.	do.	1906	14	do. 18	Apr. 23	Apr. 17	do.	June 12	Oct. 20	Nov. 1	Sept. 1	June.
83	do.	38 0	1,150	N.	Clay loam.	1907	11	Mar. 25	Mar. 29	Apr. 15	Mar. 23	do.	Oct. 10	Oct. 12	do.	do.
84	do.	38 0	1,300	N.	do.	1907	10	do.	do.	Apr. 14	do.	do.	do.	do.	do.	do.
85	do.	38 0	800	E.	do.	1907	10	do.	do.	Apr. 14	do.	do.	do.	do.	do.	do.
86	do.	38 0	1,000	E.	Clay	1905	14	Apr. 9	Apr. 18	Apr. 18	Apr. 6	May 25	Oct. 4	Oct. 12	Oct. 11	Mar.
86	do.	38 0	1,000	E.	do.	1906	15	Apr. 19	Apr. 24	Apr. 14	Apr. 10	May 25	Oct. 1	Oct. 10	Nov. 1	Do.
86	do.	38 0	1,000	E.	do.	1907	18	Mar. 26	Mar. 30	Apr. 16	Mar. 22	June 1	Sept. 22	Oct. 10	Aug. —	Jan.
87	do.	38 0	1,000	N.E.	do.	1905	13	Apr. 9	Apr. 15	do.	Mar. 27	July —	Oct. 5	Oct. 10	do.	do.
87	do.	38 0	1,000	N.E.	do.	1906	14	Apr. 21	Apr. 25	Apr. 14	Apr. 8	July 1	Oct. 5	Oct. 16	do.	do.
87	do.	38 0	1,000	N.E.	do.	1907	15	Mar. 20	Mar. 28	Apr. 23	Mar. 20	July 15	Oct. 10	Oct. 5	do.	do.
88	do.	38 0	1,100	All.	Sandy loam.	1907	10	do.	Apr. 17	May 12	Mar. 22	Aug. 1	Oct. 10	Oct. 13	Oct. 3	Do.
88	do.	38 15	750	N.E.	do.	1902	8	Apr. 12	Mar. 30	May 12	Mar. 22	Sept. 1	Sept. 29	Oct. 22	Oct. 3	Do.
89	do.	38 15	850	Level.	Black loam.	1907	10	Mar. 25	Mar. 30	Apr. 11	Mar. 29	Sept. 1	Sept. 20	Oct. 11	Sept. 30	Do.
90	do.	38 30	550	SE.	Sandy loam.	1905	12	Apr. 9	Apr. 11	Apr. 10	Apr. 19	Aug. 25	Oct. 15	Oct. 15	do.	do.
92	do.	38 30	550	SE.	do.	1906	13	Apr. 22	Apr. 26	Apr. 11	Mar. 24	Aug. 25	Oct. 21	Oct. 23	Sept. 30	Apr.
92	do.	38 30	550	SE.	do.	1907	14	Mar. 27	Mar. 30	May 2	Apr. 3	June 15	Oct. 15	Oct. 23	do.	do.
93	do.	38 30	540	All.	Clay loam.	1904	8	Apr. 23	May 1	May 2	Apr. 3	June 15	Oct. 15	Oct. 23	Sept. 30	Apr.
94	do.	38 30	500	Level.	Black loam.	1905	10	Apr. 20	Apr. 18	May 1	do.	do.	Oct. 15	Oct. 7	Sept. 20	Do.
95	do.	38 45	800	N.W.	Clay loam.	1902	7	Apr. 20	Apr. 25	Apr. 15	Apr. 26	June 15	Oct. 15	Oct. 15	Sept. 30	Dec.
95	do.	38 45	800	N.W.	do.	1903	8	Apr. 8	Apr. 16	Early	Apr. 30	June 28	Sept. 25	Oct. 11	Sept. 15	Nov.
95	do.	38 45	800	N.W.	do.	1904	9	Apr. 5	May 4	Apr. 3	Apr. 9	June 18	Oct. 15	Oct. 8	Aug. 30	Dec.
95	do.	38 45	800	N.W.	do.	1905	10	Apr. 5	Apr. 8	Apr. 3	Apr. 9	June 18	Oct. 15	Oct. 8	Aug. 30	Dec.
95	do.	38 45	800	N.W.	do.	1906	11	Apr. 20	Apr. 25	May 2	Apr. 18	June 18	Oct. 15	Oct. 8	Aug. 30	Dec.
96	do.	38 45	800	N.W.	do.	1907	Old.	Early.	Apr. 28	May 4	Apr. 18	Sept. 19	Oct. 14	Oct. 14	do.	do.
97	do.	39 0	700	W.	Clay	1902	7	Apr. 22	May 2	Apr. 8	Apr. 6	Sept. 19	Oct. 14	Oct. 18	do.	do.
97	do.	39 0	700	W.	do.	1903	8	Apr. 11	May 12	Apr. 1	Apr. 1	Aug. 29	Oct. 18	Oct. 18	do.	do.
97	do.	39 0	700	W.	do.	1904	9	Apr. 29	May 5	Apr. 25	Apr. 30	July 1	Oct. 23	Oct. 23	do.	do.
97	do.	39 0	700	W.	do.	1905	10	Apr. 10	Apr. 19	Apr. 9	Apr. 9	June 9	Oct. 21	Oct. 21	do.	do.
97	do.	39 0	700	W.	do.	1906	11	Apr. 22	Apr. 29	May 4	Apr. 20	June 16	Oct. 10	Oct. 10	do.	do.
97	do.	39 0	700	W.	do.	1907	12	Mar. 30	Apr. 9	May 4	Mar. 26	June 18	Oct. 12	Oct. 12	do.	do.
98	do.	39 0	900	S.	Sandy clay	1907	10	Mar. 30	Apr. 23	Apr. 29	do.	do.	Oct. 1	Nov. 1	Nov. 1	Apr.
99	do.	39 15	800	S.	Clay	1906	12	Apr. 21	Apr. 24	May 9	Apr. 7	do.	Oct. 1	Nov. 1	Sept. 15	Apr.
100	do.	39 15	900	S.W.	Clay loam.	1905	10	Apr. 2	Apr. 15	May 1	Apr. 4	Sept. 15	Oct. 25	Oct. 25	do.	do.
101	do.	39 15	466	S.W.	Sandy loam.	1907	5	May 3	May 6	May 1	Apr. 2	July 15	Oct. 21	Oct. 21	do.	do.
102	do.	39 30	900	S.W.	do.	1904	11	May 3	May 6	May 1	Apr. 2	July 15	Oct. 21	Oct. 21	do.	do.
102	do.	39 30	900	S.W.	do.	1905	12	Apr. 25	Apr. 28	May 10	Apr. 12	May 30	Oct. 8	Oct. 10	do.	do.
102	do.	39 30	900	S.W.	do.	1906	13	Apr. 25	Apr. 28	May 10	Apr. 12	May 30	Oct. 8	Oct. 10	do.	do.

103	do.	723	N.W.	Dark loam.	1904	May 6	May 9	Apr. 12	May 12	July 30	Nov. 10	Oct. 22	Dec. 20	May.
103	do.	723	N.W.	do.	1905	7 Apr. 27	Apr. 28	Apr. 15	Apr. 16	do.	Oct. 19	Oct. 28	Dec. 1	Apr.
103	do.	723	N.W.	do.	1906	8 Apr. 29	May 5	May 4	May 2	Aug. 10	Oct. 13	Oct. 10	Dec. 1	Apr.
104	do.	723	N.W.	do.	1907	9 Apr. 9	Apr. 27	May 4	Mar. 27	Aug. 5	Oct. 13	Oct. 12	Sept. 1	Mar.
104	do.	723	N.W.	Light loam.	1907	14 Apr. 14	Apr. 28	Apr. 15	Mar. 28	Sept. 30	Oct. 20	Nov. 25	Sept. 1	Mar.
105	do.	1,000	N.S.	Clay loam.	1904	10 Apr. 25	Apr. 28	Apr. 15	Apr. 10	July 30	Oct. 15	Nov. 25	Oct. 10	Do
105	do.	1,000	S.E.	do.	1905	11 Apr. 6	Apr. 28	Apr. 15	Apr. 10	June 30	Oct. 10	do.	Oct. 10	Do.
105	do.	1,000	S.E.	do.	1906	12 Apr. 26	May 5	Apr. 26	Mar. 28	July 20	Oct. 16	do.	Dec. 1	Do.
106	do.	850	S.E.	Clay.	1902	7 Apr. 21	May 13	Apr. 26	Apr. 21	June 20	Oct. 3	Oct. 13	Dec. 1	Do.
106	do.	850	S.E.	do.	1903	8 May 7	May 30	Apr. 22	Apr. 28	June 14	Oct. 1	Oct. 13	Nov. 10	Do.
106	do.	850	S.E.	do.	1904	9 Apr. 27	May 2	Apr. 15	Apr. 18	June 8	Oct. 1	Oct. 9	Dec. 1	Do.
106	do.	850	S.E.	do.	1905	10 Apr. 23	May 13	May 3	Apr. 8	Sept. 5	Oct. 15	Oct. 21	Nov. 1	Do.
107	do.	700	S.E.	Clay loam.	1905	6 May 4	May 13	Apr. 25	Apr. 24	Sept. 5	Oct. 20	Oct. 15	Dec. 1	Do.
108	do.	900	All.	Black loam.	1904	8 May 4	May 13	Apr. 25	Apr. 24	Sept. 5	Oct. 20	Oct. 15	Dec. 1	Do.

GRIMES.

9	Oklahoma.	1,200	W.	Sandy loam.	1905	9 Mar. 26	Apr. 14	Apr. 17	Mar. 30	Mar. 26	Sept. 1	Oct. 16	Aug. 1	Oct.
21	do.	1,000	N.W.	do.	1903	11 Apr. 10	Apr. 16	Apr. 10	Apr. 20	Mar. 26	Sept. 10	Nov. 17	Sept. 1	Sept.
23	Arkansas.	1,550	Level.	Clay loam.	1904	8 Apr. 8	Apr. 10	Apr. 10	Apr. 23	Mar. 26	Sept. 6	Nov. 17	Aug. 30	Oct.
23	do.	1,550	Level.	do.	1905	9 Apr. 2	Apr. 21	Apr. 21	Apr. 23	Mar. 26	Sept. 4	Nov. 17	Aug. 28	Oct.
23	do.	1,550	Level.	do.	1906	10 Apr. 17	Apr. 24	Apr. 24	Apr. 29	Mar. 26	Sept. 4	Nov. 17	Aug. 10	Do.
23	do.	1,550	Level.	do.	1907	11 Mar. 20	Mar. 24	Mar. 24	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
28	Oklahoma.	1,800	Level.	Sandy loam.	1907	5 Mar. 20	Mar. 27	Mar. 27	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
53	Arkansas.	1,575	N.	Chert.	1902	5 Apr. 19	Apr. 24	Apr. 24	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
63	Missouri.	1,250	S.	Clay loam.	1902	6 Apr. 26	Apr. 29	Apr. 29	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
69	do.	1,550	N.	Clay.	1902	12 Apr. 26	Apr. 29	Apr. 29	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
71	do.	1,250	N.	do.	1907	12 Apr. 26	Apr. 29	Apr. 29	Apr. 11	Mar. 26	Sept. 4	Nov. 17	Aug. 30	Do.
72	do.	1,200	Level.	Clay loam.	1904	16 Apr. 11	Apr. 20	Apr. 20	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
84	do.	1,200	N.	do.	1907	4 Apr. 27	Apr. 29	Apr. 29	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
89	do.	750	N.E.	Sandy loam.	1902	8 Apr. 24	Apr. 29	Apr. 29	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
90	do.	850	Level.	Black loam.	1907	8 Apr. 24	Apr. 29	Apr. 29	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
92	do.	550	S.E.	Sandy loam.	1905	8 Apr. 24	Apr. 29	Apr. 29	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
93	do.	540	All.	Clay loam.	1904	8 Apr. 24	Apr. 29	Apr. 29	Apr. 23	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1902	7 Apr. 6	Apr. 14	Apr. 14	Apr. 15	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1903	8 Apr. 6	Apr. 14	Apr. 14	Apr. 15	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1904	8 Apr. 6	Apr. 14	Apr. 14	Apr. 15	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1905	10 Apr. 20	Apr. 28	Apr. 28	Apr. 30	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1906	11 Apr. 20	Apr. 28	Apr. 28	Apr. 30	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
95	do.	800	N.W.	do.	1907	12 Mar. 28	Mar. 28	Mar. 28	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	Clay.	1902	5 Apr. 12	Apr. 12	Apr. 12	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	do.	1903	6 Apr. 29	Apr. 29	Apr. 29	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	do.	1904	7 Apr. 9	Apr. 9	Apr. 9	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	do.	1905	8 Apr. 27	Apr. 27	Apr. 27	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	do.	1906	9 Apr. 27	Apr. 27	Apr. 27	Apr. 1	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
97	do.	700	W.	do.	1907	10 Mar. 29	Mar. 29	Mar. 29	Apr. 4	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.
98	do.	900	S.	Sandy clay.	1907	10 Apr. 2	Apr. 2	Apr. 2	Apr. 4	Mar. 26	Sept. 10	Oct. 23	Oct. 1	Dec.

TABLE VII.—*Phenological records of apples—Continued.*
GRIMES—Continued.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
101	Missouri	•	Foot	S.	Sandy loam.	1907	5	Apr. 2	Apr. 8	May 2	Apr. 4	Sept. 15		Oct. 25		
102	do.	39 15	465	SW.	do.	1907	9	May 1	May 5		Apr. 23	July 15		Oct. 22		
103	do.	39 30	950	S. E.	Clay.	1904	6	May 29	May 2	Apr. 22	Apr. 20	June 20	Sept. 25	Oct. 13	Nov. 15	Dec.
104	do.	40 15	850	S. E.	do.	1906	10	Apr. 27	do.	May 9	Apr. 18	June 8	Sept. 27	Oct. 9	Nov. —	Jan.
106	do.	40 15	850	S. E.	do.	1906	7	Apr. 23	May 1	Apr. 15	Apr. 10	June 8		Oct. 21		
107	do.	40 15	700			1905										

INGRAM.

38	Arkansas	36 15	1,250	S.	Sandy loam.	1904	4	Apr. 15	Apr. 30	Apr. 10	Apr. 10	Nov. 1	Sept. 5	Oct. 31		
44	Oklahoma	36 15	1,000	Level.	do.	1905	8	Apr. 9	Apr. 16	Mar. 28	Apr. 6	Nov. 1	Oct. 28	Nov. 16		
55	Arkansas	36 30	1,300	E. W.	do.	1903	8	Apr. 7	Apr. 12	May 1	Mar. 15					
68	Missouri	37 0	1,350	All.	Gravel loam.	1903	6	Apr. 22	Apr. 30	Apr. 30	Apr. 18					
68	do.	37 0	1,350	All.	do.	1904	7	Apr. 19	Apr. 25			July 19		Oct. 28		
71	do.	37 0	1,250	N.	Clay.	1907	17	Mar. 27	Apr. 3	May 13				Oct. 2		
73	do.	37 15	1,000	Level.	Black loam.	1907	23	Apr. 5	Apr. 8	May 1						
79	do.	38 30	1,540	All.	Clay loam.	1904	10	May 1	May 8	May 2	Apr. 12	June 20		Oct. 23		
93	do.	39 0	700	W.	Clay.	1902	3			Apr. 8	Apr. 7	Sept. 24		Oct. 14		
97	do.	39 0	700	W.	do.	1903	4			May 1	Apr. 5	Oct. 18		Oct. 23		
97	do.	39 0	700	W.	do.	1904	5			Apr. 25	Apr. 20	July 14		Oct. 23		
97	do.	39 0	700	W.	do.	1905	6			Apr. 18	Apr. 10	June 6		Oct. 21		
97	do.	39 0	700	W.	do.	1906	7	Apr. 30	Apr. 29	May 9	Apr. 22	June 28		Oct. 10		
97	do.	39 0	700	W.	do.	1907	8	Apr. 24	Apr. 29	May 4	Mar. 23	June 20		Oct. 12		

JONATHAN.

9	Oklahoma	35 15	1,200	W.	Sandy loam.	1905	9	Apr. 2	Apr. 10	Mar. 13	Mar. 26	Aug. 30	Sept. 30	Oct. 16	Sept. —	Dec.
13	do.	36 15	1,250	N. E.	do.	1906	14	Mar. 20	Apr. 26	Apr. 20	Apr. 30	Oct. 1	Aug. 15	Nov. 8	July 25	Oct.
13	do.	36 15	1,250	N. E.	do.	1907	15	Apr. 10	Apr. 12	Mar. 3	Mar. 28	June 15	Sept. 1	Nov. 13	Aug. 1	Jan.
16	Arkansas	35 30	1,100	W. E.	do.	1906	6	Apr. 16	Apr. 24	Feb. 3	Mar. 6	Sept. 1	Aug. 20	Nov. 11	Oct. —	Dec.
16	do.	35 30	1,100	W. E.	do.	1907	10	Mar. 22	Mar. 26	Apr. 30		Sept. 1	Sept. 1	Nov. 17	Aug. 15	Sept.
21	Oklahoma	35 45	1,000	N. W.	do.	1903	14	Mar. 23	Mar. 26	Apr. 10			Aug. 15	Nov. 11	Aug. 1	Oct.
21	do.	35 45	1,000	N. W.	do.	1907										

PHENOLOGICAL RECORDS.

22	do.	922	S.	do.	1904	9	Apr. 20	Apr. 27	Mar. 26	Apr. 17	May 28	Oct. 26	Sept. 2	Oct. Do.
23	do.	922	S.	do.	1904	7	Apr. 4	Apr. 6	Apr. 5	Apr. 7	Apr. 29	Oct. 11	Sept. 1	Oct. Do.
24	Arkansas.	1,830	Level	Clay loam.	1905	8	do.	Apr. 20	Early	Apr. 7	June 8	Oct. 31	Sept. 2	Oct. Do.
25	do.	1,830	Level	do.	1907	9	Apr. 11	Apr. 23	Apr. 13	do.	July 24	Nov. 15	Oct. 1	Jan. Do.
26	do.	1,830	E. S.	Sandy loam.	1906	9	Mar. 17	Apr. 26	Feb. 5	Mar. 17	Sept. 24	Oct. 16	Sept. 1	Jan. Do.
27	do.	1,830	N. W.	do.	1906	5	Apr. 20	Apr. 17	Apr. 5	do.	Sept. 24	Oct. 16	Sept. 1	Feb. Do.
28	do.	1,830	Level	do.	1907	5	Mar. 23	Apr. 20	Apr. 5	Apr. 20	Aug. 6	Nov. 1	Oct. 1	Do.
29	Oklahoma.	1,250	N. W.	do.	1904	7	Apr. 23	Apr. 26	Apr. 5	Apr. 20	Aug. 6	Nov. 1	Oct. 1	Do.
30	Arkansas.	1,000	Level	do.	1905	5	Mar. 5	Apr. 26	Mar. 28	Mar. 18	Oct. 25	Nov. 1	Aug. 25	Oct. Do.
31	do.	915	E.	do.	1907	11	Mar. 18	Apr. 26	Mar. 31	Mar. 21	Oct. 25	Nov. 1	Aug. 25	Oct. Do.
32	do.	1,400	N.	Clay loam.	1902	9	Apr. 16	Apr. 20	Apr. 13	Mar. 25	June 10	Oct. 9	Aug. 15	Feb. Do.
33	Arkansas.	1,300	E. W.	Sandy loam.	1903	8	Mar. 23	Apr. 27	Apr. 13	Mar. 25	June 10	Oct. 9	Aug. 20	Oct. Do.
34	do.	1,300	Level	do.	1905	7	Apr. 23	Apr. 27	Apr. 13	Mar. 25	June 10	Oct. 9	Aug. 20	Oct. Do.
35	do.	1,100	N.	Clay loam.	1907	10	Apr. 22	Apr. 25	Apr. 20	Apr. 3	July 6	Nov. 1	Aug. 15	Oct. Do.
36	Oklahoma.	1,400	W.	Sandy loam.	1903	7	Apr. 14	Apr. 23	May 1	do.	June 10	Oct. 9	Aug. 15	Oct. Do.
37	Missouri.	1,250	S.	Clay loam.	1902	6	Apr. 24	Apr. 29	May 1	do.	June 10	Oct. 9	Aug. 15	Oct. Do.
38	do.	1,650	N.	Clay	1902	7	Apr. 27	Apr. 31	Mar. 15	Apr. 19	June 10	Oct. 9	Aug. 15	Dec. Do.
39	do.	1,650	N.	Chert.	1902	10	Mar. 27	Mar. 31	Mar. 13	Apr. 19	June 10	Oct. 9	Aug. 15	Dec. Do.
40	do.	1,000	Level.	Light loam.	1905	12	Apr. 7	Apr. 21	Mar. 8	Apr. 21	May 31	Oct. 2	Oct. 15	Dec. Do.
41	Oklahoma.	1,350	N.	Clay loam.	1907	14	Mar. 26	Mar. 29	Mar. 8	Apr. 21	May 31	Oct. 2	Oct. 15	Dec. Do.
42	Missouri.	1,000	E.	Clay	1905	15	Apr. 21	Apr. 24	Apr. 25	Apr. 10	May 21	Oct. 20	Sept. 15	Sept. Do.
43	do.	1,000	E.	do.	1906	13	Mar. 26	Apr. 24	Apr. 16	Apr. 22	June 10	Oct. 20	Sept. 15	Sept. Do.
44	do.	1,000	E.	do.	1907	16	Mar. 26	Apr. 24	Apr. 16	Apr. 22	June 10	Oct. 20	Sept. 15	Sept. Do.
45	do.	1,000	W.	do.	1905	3	Apr. 21	Apr. 25	Apr. 15	Apr. 22	July —	Oct. 10	Aug. 20	Sept. Do.
46	do.	1,000	W.	do.	1906	4	Mar. 25	Apr. 30	Apr. 16	Apr. 22	July —	Oct. 10	Aug. 20	Sept. Do.
47	do.	1,000	W.	do.	1907	5	Mar. 25	Apr. 30	Apr. 16	Apr. 22	July —	Oct. 10	Aug. 20	Sept. Do.
48	do.	1,000	W.	do.	1907	4	Mar. 25	Apr. 30	Apr. 16	Apr. 22	July —	Oct. 10	Aug. 20	Sept. Do.
49	do.	1,100	All	Sandy loam.	1902	6	Mar. 24	Mar. 29	Apr. 23	Mar. 20	July 15	Oct. 5	Sept. 1	Oct. Do.
50	do.	750	N. E.	do.	1907	12	Apr. 14	Mar. 29	Apr. 23	Mar. 20	July 15	Oct. 5	Sept. 1	Oct. Do.
51	do.	850	Level.	Black loam.	1907	12	Apr. 24	Mar. 26	May 12	Mar. 20	Aug. 1	Oct. 13	Sept. 1	Oct. Do.
52	do.	902	W.	Clay.	1902	7	Early	Mar. 26	May 4	Mar. 20	Aug. 1	Oct. 13	Sept. 1	Oct. Do.
53	do.	700	W.	do.	1903	8	Apr. 21	May 2	Apr. 8	Apr. 2	Sept. 22	Oct. 14	Sept. 1	Oct. Do.
54	do.	700	W.	do.	1904	9	Apr. 23	May 12	May 1	Apr. 1	Aug. 1	Oct. 18	Sept. 14	Oct. Do.
55	do.	700	W.	do.	1905	10	Apr. 27	May 16	Apr. 25	Apr. 22	July 6	Oct. 23	Sept. 14	Oct. Do.
56	do.	700	W.	do.	1906	11	Apr. 22	Apr. 10	Apr. 9	Apr. 27	June 6	Oct. 21	Sept. 18	Oct. Do.
57	do.	700	W.	do.	1907	12	Mar. 28	Apr. 23	May 4	Apr. 27	June 21	Oct. 12	Sept. 19	Oct. Do.
58	do.	900	S.	Sandy clay.	1906	8	Mar. 28	Apr. 23	Apr. 20	Mar. 26	July 21	Oct. 17	Sept. 25	Feb. Do.
59	do.	900	All	Clay	1906	8	Apr. 2	Apr. 23	May 2	Apr. 10	Sept. 15	Oct. 1	Sept. 25	Jan. Do.
60	do.	465	S.	Sandy loam.	1907	5	Apr. 5	May 8	May 2	Apr. 4	Sept. 15	Oct. 22	Sept. 25	Jan. Do.
61	do.	900	SW.	do.	1904	9	May 1	Apr. 19	Apr. 18	Apr. 25	Sept. 15	Oct. 22	Sept. 17	Jan. Do.
62	do.	900	SW.	do.	1905	11	Apr. 24	Apr. 27	May 10	Apr. 13	May 30	Oct. 12	Sept. 17	Jan. Do.
63	do.	900	SW.	do.	1906	11	Apr. 24	Apr. 27	Apr. 25	Apr. 26	Sept. 15	Oct. 12	Sept. 17	Jan. Do.
64	do.	700	E. N.	Light loam.	1907	9	Apr. 9	do.	Apr. 15	Apr. 26	Sept. 15	Oct. 12	Aug. 10	Dec. Do.
65	do.	1,000	E. N.	Clay loam.	1904	14	do.	do.	do.	Apr. 26	Sept. 15	Nov. 1	Aug. 10	Dec. Do.
66	do.	1,000	S.	do.	1905	5	Apr. 25	Apr. 27	do.	Apr. 26	Sept. 15	Nov. 1	Aug. 10	Dec. Do.
67	do.	1,000	S.	do.	1906	6	Apr. 18	Apr. 25	do.	Apr. 26	Sept. 15	Nov. 1	Aug. 10	Dec. Do.
68	do.	1,700	E.	do.	1905	10	Apr. 25	Apr. 27	Apr. 15	Apr. 22	June 5	Oct. 21	Aug. 10	Dec. Do.
69	do.	1,700	E.	do.	1906	10	Apr. 18	Apr. 25	Apr. 15	Apr. 22	June 5	Oct. 21	Aug. 10	Dec. Do.
70	do.	1,700	E.	do.	1905	10	Apr. 18	Apr. 25	Apr. 15	Apr. 22	June 5	Oct. 21	Aug. 10	Dec. Do.

TABLE VII.—*Phenological records of apples*—Continued.

MAIDEN BLUSH.

Ob- serv- er's No.	State.	Ap- proxi- mate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first pickling).	Date first fall frost.	Date fit for use.	Keeps until—
14	Oklahoma.....	35 15	1,050	SE.	Clay loam.....	1902	Yr. 8	Apr. 11	Mar. 29	Apr. 11	Apr. 11	July 20	Oct. 6	Aug. 1	Nov.
17	do.....	35 30	1,250	W.	Sandy loam.....	1904	12	Mar. 20	Mar. 26	Mar. 25	Apr. 15	Aug. 1	Oct. 11	Aug. 2	Sept.
22	do.....	35 45	1,092	S.	do.....	1905	8	Apr. 11	Apr. 17	Mar. 26	Apr. 15	Aug. 30	Nov. 1	Aug. 2	Do.
23	Arkansas.....	36 0	1,850	Level.	Clay loam.....	1904	8	Apr. 11	Apr. 17	Mar. 26	Apr. 15	Aug. 30	Nov. 1	Aug. 2	Do.
23	do.....	36 0	1,850	Level.	do.....	1905	9	Apr. 18	Early	Apr. 6	June 26	July 30	Oct. 31	July 30	Do.
23	do.....	36 0	1,850	Level.	do.....	1906	10	Apr. 18	Feb. 5	Apr. 10	June 22	July 30	Oct. 15	Aug. 30	Do.
23	do.....	36 0	1,850	Level.	do.....	1907	11	Mar. 20	Mar. 23	Mar. 18	June 24	Aug. 14	Oct. 15	Aug. 30	Do.
33	do.....	36 15	1,800	W.	Clay loam.....	1902	10	Apr. 4	Mar. 23	Apr. 10	June 20	Sept. 10	Nov. 11	July 1	Do.
46	Oklahoma.....	36 15	1,300	W.	Sandy loam.....	1906	10	Mar. 22	Apr. 16	Mar. 16	June 15	July 15	Nov. 11	July 1	Do.
71	do.....	37 0	1,400	W.	do.....	1907	10	Mar. 24	Apr. 27	Mar. 13	June 9	July 15	Oct. 23	Aug. 4	Aug. Sept.
72	Missouri.....	37 0	1,300	N.	Clay.....	1904	12	Apr. 24	Apr. 21	Apr. 2	June 9	Aug. 14	Oct. 10	Aug. 1	Aug. Sept.
74	Oklahoma.....	37 0	1,150	Level.	Light loam.....	1905	12	Mar. 18	Apr. 17	Apr. 4	May 25	Aug. 13	Oct. 12	Aug. 1	Aug. Sept.
83	Missouri.....	38 0	1,150	N.	Clay.....	1907	10	Mar. 18	Apr. 17	Apr. 4	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
86	do.....	38 0	1,000	E.	do.....	1905	19	Apr. 9	Apr. 25	Apr. 4	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
86	do.....	38 0	1,000	E.	do.....	1906	20	Apr. 26	Apr. 25	Apr. 4	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
86	do.....	38 0	1,000	E.	do.....	1907	21	Mar. 26	May 3	Apr. 14	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1902	6	Apr. 22	May 12	Apr. 14	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1903	7	Apr. 10	May 3	Apr. 14	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1904	8	Apr. 26	May 23	Apr. 14	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1905	9	Apr. 10	May 3	Apr. 14	May 25	Aug. 13	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1906	10	Apr. 23	May 9	Apr. 21	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
97	do.....	39 0	700	W.	do.....	1907	11	Mar. 23	Apr. 9	Apr. 21	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
98	do.....	39 0	900	S.	do.....	1907	10	do.....	Apr. 20	Apr. 28	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
98	do.....	39 0	900	S.	Sandy clay.....	1907	10	do.....	Apr. 20	Apr. 28	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
106	do.....	40 15	850	S. E.	Clay.....	1902	7	Apr. 28	Apr. 20	Apr. 20	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
106	do.....	40 15	850	S. E.	do.....	1903	6	Apr. 27	Apr. 25	Apr. 20	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.
106	do.....	40 15	850	S. E.	do.....	1904	10	Apr. 21	May 3	Apr. 9	June 20	Aug. 1	Oct. 10	Aug. 1	Aug. Sept.

OLDENBURG.

4	Arkansas.....	34 30	1,250	E.	Sandy loam.....	1907	6	Mar. 20	Mar. 25	Mar. 2	June 29	July 10	Nov. 10	July 28	July.
21	Oklahoma.....	35 46	1,000	NW.	do.....	1903	11	Apr. 8	Apr. 12	Apr. 17	June 29	July 25	Nov. 17	June 28	Aug.
22	Arkansas.....	36 0	1,850	Level.	Clay loam.....	1904	7	Apr. 30	do.....	Apr. 10	July 10	Aug. 31	Nov. 31	July 10	Do.
23	do.....	36 0	1,850	Level.	do.....	1905	8	Apr. 12	Early	Apr. 6	July 10	Aug. 6	Nov. 1	July 10	Do.
23	do.....	36 0	1,850	Level.	do.....	1906	9	Apr. 18	Feb. 5	Apr. 10	July 10	Aug. 6	Nov. 1	July 10	Do.
23	do.....	36 0	1,850	Level.	do.....	1907	10	Mar. 17	Apr. 13	Mar. 25	June 24	Aug. 1	Nov. 15	Aug. 1	Do.
23	do.....	36 0	1,850	Level.	do.....	1908	9	Apr. 1	Apr. 5	Mar. 25	June 24	Aug. 1	Nov. 15	Aug. 1	Do.
23	do.....	36 0	1,400	NW.	Sandy loam.....	1905	10	Apr. 21	Apr. 10	Mar. 25	June 24	Aug. 1	Nov. 15	Aug. 1	Do.

44	Oklahoma	86	15	1,000	Level.	Sandy loam.	1905	6	Apr. 7	Apr. 15	Mar. 28	Apr. 1	Oct. 28	Oct. 21	July.
55	Arkansas	36	30	1,300	E. W.	do.	1905	4	Apr. 6	Apr. 14	May 1	Mar. 20	Oct. 11	Nov. 16	
58	do.	36	30	1,100	N. W.	Clay loam.	1905	7	Apr. 30	Apr. 22	Apr. 22	Mar. 12	Oct. 10	Oct. 11	
73	Missouri	37	0	1,000	Level.	Light loam.	1905	9	Apr. 6	Apr. 20	May 8	Apr. 5	June 3	July 1	
74	Oklahoma	37	0	1,150	All.	Clay loam.	1905	10	Apr. 1	Apr. 13	May 1	Apr. 20	Oct. 20	Oct. 2	
78	Missouri	37	15	1,000	S. E.	do.	1905	16	Apr. 4	Apr. 11	Apr. 21	Mar. 29	Oct. 22	Nov. 13	
82	do.	38	30	550	W.	Sandy loam.	1905	12	Apr. 21	May 1	Apr. 8	Apr. 1	Sept. 18	Oct. 14	
97	do.	39	0	700	W.	Clay	1905	8	Apr. 10	May 12	May 1	Apr. 2	Oct. 18	Oct. 18	
97	do.	39	0	700	W.	do.	1904	9	Apr. 26	May 3	Apr. 25	Apr. 24	July 5	Oct. 23	July 20
97	do.	39	0	700	W.	do.	1905	10	Apr. 5	May 15	Apr. 18	Apr. 17	June 4	Oct. 21	July 1
97	do.	39	0	700	W.	do.	1906	11	Apr. 20	Apr. 26	May 9	Apr. 17	June 15	Oct. 7	July 3
97	do.	39	0	700	W.	do.	1907	12	Mar. 27	Apr. 7	May 4	Mar. 27	July 20	Oct. 10	July 3
97	do.	39	0	700	W.	do.	1907	14	Apr. 10	Apr. 15	Apr. 15	Apr. 26	July 15	Oct. 12	July 3
105	do.	39	30	1,000	N. S.	Clay loam.	1905	15	Apr. 22	Apr. 25	May 9	Apr. 16	June 24	Nov. 25	Aug. 25
105	do.	39	30	1,000	S. E.	do.	1906	16	Apr. 27	Apr. 28	May 3	Apr. 21	July 27	Nov. 1	Sept. 20
105	do.	39	30	1,000	S. E.	do.	1907	17	May 5	May 9	May 9	Apr. 28	Oct. 10	June 20	July.
106	do.	40	15	850	S. E.	Clay	1904	7	May 5	May 9	Apr. 22	Apr. 10	July 15	Oct. 10	June 21
106	do.	40	15	850	S. E.	do.	1905	8	Apr. 17	Apr. 28	Apr. 22	Apr. 10	July 15	Oct. 10	June 21
106	do.	40	15	850	S. E.	do.	1906	9	Apr. 24	May 1	May 9	Apr. 18	Aug. 3	Oct. 9	Sept. 20
108	do.	40	30	760	Level.	Clay loam.	1903	4	Apr. 23	Apr. 27	May 3	Apr. 15	Sept. 5	Oct. 9	Sept. 20

RED JUNE.

1	Arkansas	33	45	400	Level.	Sandy clay	1905	7	Mar. 25	Mar. 31	Mar. 21	Mar. 22	May 29	June 5	June 5
11	do.	35	15	500	N. S.	do.	1905	6	Mar. 23	Apr. 6	Mar. 21	Mar. 22	June 15	June 20	June 20
21	Oklahoma	35	45	1,000	N. W.	Sandy loam.	1905	10	Apr. 2	Apr. 6	Apr. 30	Mar. 22	June 24	Nov. 17	June 20
21	do.	35	45	1,000	N. W.	do.	1907	14	Mar. 20	Apr. 2	Apr. 19	Mar. 22	June 24	Nov. 17	June 20
22	do.	35	45	922	S.	do.	1904	19	Apr. 20	Apr. 20	Mar. 25	Mar. 22	Aug. 2	Oct. 11	July 2
22	do.	35	45	922	S.	Clay loam.	1905	7	Apr. 20	Apr. 20	Apr. 10	Mar. 22	Aug. 2	Oct. 11	July 2
23	Arkansas	36	0	1,850	Level.	do.	1904	7	Apr. 2	Apr. 14	Apr. 17	Mar. 25	Aug. 10	Nov. 31	Aug. 2
23	do.	36	0	1,850	Level.	do.	1905	8	Apr. 19	Apr. 22	Early 5	Apr. 18	Aug. 2	Nov. 31	Aug. 2
23	do.	36	0	1,850	Level.	do.	1906	9	Apr. 22	Apr. 22	Apr. 13	Apr. 18	Aug. 2	Nov. 31	Aug. 2
23	do.	36	0	1,850	Level.	do.	1907	10	Mar. 22	Mar. 23	Feb. 13	Mar. 18	June 24	Nov. 31	Aug. 2
28	Oklahoma	36	0	800	Level.	Sandy loam.	1907	5	Mar. 18	Mar. 26	Feb. 13	Mar. 18	June 24	Nov. 31	Aug. 2
38	Missouri	38	0	1,100	All.	do.	1907	6	Mar. 25	Mar. 26	Apr. 23	Mar. 21	July 15	Oct. 5	June 29
66	do.	38	45	850	S. E.	Clay	1907	Old	Early 4	Mar. 26	Apr. 4	Apr. 19	June 20	Oct. 13	June 29
106	do.	40	15	850	S. E.	do.	1902	8	Apr. 27	May 2	Apr. 22	Apr. 28	July 10	Oct. 13	June 29
106	do.	40	15	850	S. E.	do.	1904	8	May 5	May 10	May 9	Apr. 18	Aug. 2	Oct. 9	June 29
106	do.	40	15	850	S. E.	do.	1906	10	Apr. 25	May 1	May 9	Apr. 18	Aug. 2	Oct. 9	June 29

STAYMAN WINESAP.

23	Arkansas	36	0	1,850	Level.	Clay loam.	1905	10	Mar. 30	Apr. 4	Early 5	Apr. 10	July 1	Sept. 20	Oct. 20
23	do.	36	0	1,850	Level.	do.	1906	11	Apr. 18	Apr. 22	Feb. 5	Apr. 17	July 5	Nov. 10	Dec. 1
23	do.	36	0	1,850	Level.	do.	1907	12	Mar. 20	Mar. 24	Apr. 13	Mar. 17	June 24	Nov. 10	Dec. 1
97	Missouri	39	0	700	W.	Clay	1902	5	Apr. 11	Apr. 14	Apr. 1	Apr. 2	Sept. 18	Oct. 14	Nov. 1
97	do.	39	0	700	W.	do.	1903	6	Apr. 11	Apr. 14	May 1	Apr. 2	Aug. 31	Oct. 18	Nov. 1

TABLE VII.—*Phenological records of apples*—Continued.

STAYMAN WINESAP—Continued.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date fit for use.	Keeps until—
97	Missouri	39 0	700	W.	Clay	1904	7	Apr. 30	May 6	Apr. 25	Apr. 25	July 13	Sept. 15	Oct. 23	
97	do.	39 0	700	W.	do.	1905	8	Apr. 10	Apr. 21	Apr. 18	Apr. 9	June 9	Oct. 21	Oct. 21	
97	do.	39 0	700	W.	do.	1906	9	Apr. 9	Apr. 21	May 9	Mar. 26	June 30	Oct. 10	Oct. 10	
97	do.	39 0	700	W.	do.	1907	10	Mar. 28	Apr. 9	May 4	Mar. 26	July 15	Oct. 12	Oct. 12	

WINESAP.

1	Arkansas	33 45	400	Level.	Sandy clay	1905	9	Mar. 25	Mar. 31	Mar. 2	Mar. 21		Sept. 1	Nov. 10	Mar.
4	do.	34 30	1,250	E.	Sandy loam.	1907	10	Mar. 24	Mar. 29	do.	Apr. 10		Oct. 1	Oct. 1	
5	do.	34 30	1,350	SE.	do.	1907	6	Mar. 25	Mar. 30	Feb. 16	Mar. 30		Oct. 15	Nov. 10	
7	do.	35 0	287	S.	do.	1903	12	Apr. 14	Apr. 19	Mar. 7	Mar. 28		Oct. 15	Oct. 10	
8	Oklahoma	35 15	1,026	S.	Clay loam.	1906	9	Apr. 2	Apr. 5	Mar. 21	Mar. 28		Sept. 20	Nov. 23	
9	do.	35 15	1,200	SE.	Sandy loam.	1905	10	Mar. 28	Apr. 2	Mar. 20	Apr. 4		Oct. 1	Nov. 3	
12	Arkansas	35 15	280	SE.	do.	1904	10	Apr. 19	Apr. 21	Mar. 13	Apr. 21		Sept. 14	Nov. 8	Dec.
13	Oklahoma	35 15	1,250	NE.	do.	1906	15	Mar. 14	Apr. 12	Feb. 18	Apr. 10		Sept. 10	Nov. 26	May.
13	do.	35 15	1,250	NE.	do.	1907	15	Mar. 12	Apr. 10	Feb. 30	Apr. 20		Sept. 10	Dec. —	Spring.
16	Arkansas	35 30	1,100	W.	do.	1902	21	Mar. 28	Apr. 6	Mar. 3	Mar. 23		do.	Dec. —	Mar.
16	do.	35 30	1,100	W.	do.	1903	21	Mar. 28	Apr. 6	Mar. 3	Mar. 23		Sept. 15	Nov. 28	Feb.
16	do.	35 30	1,100	W.	do.	1906	23	do.	do.	Feb. 3	Mar. 24		Sept. 20	Nov. 13	Do.
16	do.	35 30	1,100	W.	do.	1906	24	Apr. 18	Apr. 23	Feb. 3	Mar. 15		do.	Nov. 11	Jan.
16	do.	35 30	1,100	W.	do.	1907	25	Apr. 3	Apr. 28	Feb. 26	Apr. 1		Oct. 1	Nov. 9	Apr.
17	Oklahoma	35 30	1,250	N.	do.	1904	12	Apr. 3	Apr. 7	Apr. 19	Apr. 1		Nov. 1	Nov. 17	Jan.
21	do.	35 45	1,000	NW.	do.	1903	14	Apr. 24	Apr. 13	Apr. 19	Apr. 1		Oct. 11	Nov. 11	Do.
21	do.	35 45	1,000	NW.	do.	1907	14	Apr. 24	Apr. 13	Apr. 19	Apr. 1		Oct. 11	Nov. 11	Do.
22	do.	35 45	992	S.	do.	1904	9	Apr. 20	Apr. 30	Apr. 26	Apr. 17		Oct. 11	Oct. 26	Do.
22	do.	35 45	992	S.	do.	1906	10	Apr. 4	Apr. 5	Apr. 6	Apr. 25		Oct. 3	Oct. 11	Do.
23	Arkansas	36 0	1,850	Level.	Clay loam.	1904	9	Apr. 3	Apr. 26	Apr. 17	Mar. 28		Oct. 3	Nov. 16	Dec. 30
24	do.	36 0	1,480	E.S.	Sandy loam.	1907	18	Apr. 22	Apr. 26	Feb. 1	Mar. 17		Sept. 20	Oct. 1	Dec. 1
25	do.	36 0	800	NW.	do.	1905	8	Apr. 6	Apr. 16	Feb. 5	Apr. 3		Oct. 10	Nov. 10	Spring.
28	Oklahoma	36 0	800	Level.	do.	1907	5	Apr. 3	Apr. 10	Feb. 10	Apr. 3		Oct. 1	Nov. 1	Apr.
29	Arkansas	36 0	1,650	Level.	do.	1906	15	Apr. 12	Apr. 22	Mar. 22	Apr. 3		Oct. 1	Sept. 27	Dec. 1
31	Oklahoma	36 15	900	E.	do.	1903	4	Mar. 25	Apr. 1	May 1	Apr. 7		Sept. 25	Oct. 20	Spring.
32	Oklahoma	36 15	1,350	Level.	Clay loam.	1904	8	Mar. 25	Apr. 4	Apr. 15	Mar. 20		Oct. 1	Oct. 20	Dec. —
33	do.	36 15	1,300	W.	do.	1902	16	Mar. 20	Apr. 7	Mar. 23	Apr. 10		Oct. 1	Oct. 20	Dec. —
34	do.	36 15	1,400	S.	Clay loam.	1907	16	Mar. 20	Apr. 7	May 14	Mar. 16		Oct. 15	Nov. 10	Spring.
35	do.	36 15	1,200	S.	do.	1907	16	Mar. 20	Apr. 7	May 15	Mar. 16		Oct. 15	Nov. 10	Spring.
35	do.	36 15	1,200	S.	Clay loam.	1907	16	Mar. 20	Apr. 7	May 15	Mar. 16		Oct. 15	Nov. 10	Spring.
36	do.	36 15	1,237	S.	Gravelly clay	1907	16	Mar. 20	Mar. 29	May 15	Mar. 16		Oct. 15	Nov. 10	Spring.

PHENOLOGICAL RECORDS.

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TABLE VII.—*Phenological records of apples*—Continued.
WINESAP—Continued.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first pick- ing).	Date first fall frost.	Date fit for use.	Keeps until—
97	Missouri	39 0	700	W.	Clay	1906	10	Apr. 24	Apr. 29	May 9	Apr. 20	June 20	.....	Oct. 10	.....	.....
97	do.	39 0	700	W.	do.	1907	11	Mar. 28	Apr. 6	May 4	Mar. 27	July 11	.....	Oct. 12	.....	.....
98	do.	39 0	900	S.	Sandy clay	1907	10	Mar. 30	Apr. 22	May 4	Mar. 28	.....	.....	Oct. 17	.....	.....
101	do.	39 15	446	S.	Sandy loam	1907	5	Apr. 2	Apr. 8	May 2	Apr. 4	Sept. 15	.....	Oct. 25	.....	.....
103	do.	39 30	725	N.W.	Dark loam	1904	6	May 7	May 12	Apr. 18	May 13	Aug. 2	Nov. 10	Oct. 28	Dec. 10	May.
103	do.	39 30	725	N.W.	do.	1905	7	Apr. 17	May 2	Apr. 15	May 4	do.	.....	Oct. 22	Dec. 1	Mar.
103	do.	39 30	725	N.W.	do.	1906	8	Apr. 29	May 5	Apr. 9	May 2	Aug. 10	Oct. 17	Oct. 20	Dec. 1	Mar.
103	do.	39 30	725	N.W.	do.	1907	9	Apr. 9	Apr. 24	May 4	Mar. 26	do.	Oct. 15	Oct. 13	Sept. 1	Do.
104	do.	39 30	700	N.W.	Light loam	1907	9	Apr. 15	Apr. 28	Apr. 15	Apr. 20	June 30	Oct. 15	Nov. 25	Oct. 25	Do.
105	do.	39 30	1,000	N., S.	Clay loam	1905	10	Apr. 26	May 3	Apr. 9	Apr. 8	.....	.....	Oct. 16	Oct. 25	Do.
105	do.	39 30	1,000	N., S.	do.	1905	11	Apr. 26	May 3	Apr. 9	Apr. 8	.....	.....	Oct. 16	Oct. 25	Do.
107	do.	40 15	700	.....	.....	1905	10	Apr. 28	May 3	Apr. 15	Apr. 8	.....	.....	Oct. 21	.....	.....

YELLOW TRANSPARENT.

4	Arkansas	34 30	1,250	E.	Sandy loam	1907	8	Mar. 23	Mar. 28	Mar. 2	Apr. 1	.....	June 25	Nov. 10	June 10	Aug.
5	do.	34 30	1,350	S.E.	do.	1907	4	Mar. 25	Mar. 31	do.	Apr. 30	.....	June 15	do.	.....	.....
7	do.	35 0	287	S.	do.	1903	12	Apr. 8	Apr. 9	Feb. 16	Mar. 27	.....	Oct. 21	Oct. 10	.....	.....
8	Oklahoma	35 15	1,026	S.	Clay loam	1905	3	Apr. 15	Apr. 20	Mar. 20	Apr. 8	.....	June 8	Oct. 10	June 15	.....
8	do.	35 15	1,026	S.	do.	1906	9	Apr. 15	Apr. 20	Mar. 20	Apr. 8	.....	June 8	Oct. 10	June 15	.....
9	do.	35 15	1,200	W.	Sandy loam	1905	4	Mar. 28	Apr. 2	Mar. 21	Mar. 25	.....	June 13	Nov. 23	June 6	.....
12	Arkansas	35 45	260	S.E.	do.	1904	11	Mar. 29	do.	Mar. 21	Mar. 25	.....	June 13	Nov. 23	June 6	.....
21	do.	35 45	992	S.	do.	1903	9	Apr. 10	Apr. 15	Mar. 30	Apr. 1	May 20	June 13	Nov. 23	June 6	.....
22	do.	35 45	992	S.	do.	1904	10	Apr. 10	Apr. 15	Mar. 30	Apr. 1	May 20	June 13	Nov. 23	June 6	.....
23	Arkansas	36 0	1,850	Level	Clay loam	1905	7	Apr. 12	Apr. 16	Apr. 5	Apr. 24	Apr. 15	July 19	Nov. 11	June 20	.....
23	do.	36 0	1,850	Level	do.	1906	8	Apr. 6	Apr. 10	Apr. 17	Mar. 25	July 2	July 22	Nov. 11	June 20	.....
23	do.	36 0	1,850	Level	do.	1906	9	Apr. 17	Apr. 21	Early	Apr. 11	June 5	July 28	Nov. 11	June 14	.....
23	do.	36 0	1,850	Level	do.	1907	10	Apr. 23	Apr. 27	Apr. 13	Mar. 20	June 24	July 28	Nov. 11	June 14	.....
25	do.	36 0	1,400	N.W.	do.	1905	9	Apr. 1	Apr. 21	Apr. 5	Mar. 25	Aug. 1	July 16	Nov. 10	Aug. 1	.....
26	do.	36 0	1,450	SW.	Sandy loam	1906	.....	Mar. 12	Mar. 28	Apr. 5	Apr. 19	.....	.....	.....	.....	.....
26	do.	36 0	1,450	SW.	do.	1907	.....	Mar. 12	Mar. 28	Apr. 5	Apr. 19	.....	.....	.....	.....	.....
34	do.	36 15	1,400	S.	Clay	1907	16	Mar. 10	Mar. 28	May 14	Mar. 10	.....	June 28	Nov. 11	June 15	.....
42	Oklahoma	36 15	700	N.W.	Sandy loam	1907	5	Mar. 23	Mar. 28	Mar. 5	Mar. 10	.....	June 8	Nov. 26	June 8	.....
50	do.	36 30	1,500	SW.	Chert	1907	7	Apr. 17	Apr. 23	Mar. 31	Apr. 3	.....	July 1	Nov. 27	June 8	.....
55	Arkansas	36 30	1,300	E., W.	Sandy loam	1902	3	Apr. 16	Apr. 19	Mar. 19	Apr. 3	.....	.....	Nov. 27	.....	.....
55	do.	36 30	1,300	E., W.	do.	1903	4	Apr. 6	Apr. 14	May 1	Mar. 12	.....	.....	Nov. 27	.....	.....

YORK IMPERIAL.

56	do.	36	30	925	N. E.	Chert.	1906	Apr. 14	Apr. 18	Apr. 22	Mar. 29	.....	July 20	Oct. 11	July 15
57	do.	36	30	1,000	N. E.	Clay loam.	1905	7	Apr. 2	Apr. 10	Mar. 29	.....	.....	.....	.....
58	do.	37	13	1,000	All.	do.	1903	16	Apr. 8	May 1	Apr. 17	.....	.....	Nov. 13	.....
73	Missouri.	27	45	1,920	Level.	Sandy loam.	1906	7	Apr. 10	Apr. 20	Apr. 8	.....	.....	.....	.....
81	do.	38	0	1,450	S. E.	Clay	1902	9	Apr. 10	Apr. 15	Apr. 17	.....	.....	.....	Aug.
82	do.	38	0	1,450	S. E.	do.	1904	7	Apr. 25	Apr. 18	Apr. 20	.....	.....	.....	.....
83	do.	38	0	1,450	S. E.	do.	1908	10	Apr. 25	Apr. 25	Apr. 24	.....	.....	Nov. 12	.....
84	do.	38	0	1,450	S. E.	do.	1908	11	Apr. 25	Apr. 25	Apr. 24	.....	.....	Nov. 12	.....
90	do.	38	0	1,450	Level.	do.	1907	10	Mar. 28	Apr. 12	Apr. 23	.....	.....	Oct. 1	.....
91	do.	38	15	850	Level.	Black loam.	1905	10	Mar. 28	Apr. 10	Mar. 25	.....	.....	Oct. 22	.....
92	do.	38	30	550	S. E.	Sandy loam.	1907	12	Mar. 26	Apr. 10	Apr. 18	.....	.....	Oct. 22	.....
92	do.	38	30	550	S. E.	do.	1908	13	Mar. 26	Apr. 25	Apr. 24	.....	.....	Oct. 11	.....
92	do.	38	30	550	S. E.	do.	1907	14	Mar. 27	Mar. 30	Apr. 24	.....	.....	Oct. 15	.....
93	do.	38	30	540	All.	Clay loam.	1904	8	Mar. 27	Apr. 11	Mar. 30	.....	.....	Oct. 23	.....
94	do.	38	30	540	Level.	Black loam.	1905	10	Apr. 17	Apr. 2	Mar. 29	.....	.....	.....	.....
105	do.	39	30	1,000	N. E.	Clay loam.	1904	14	Apr. 12	Apr. 15	Apr. 26	.....	.....	Nov. 1	.....
105	do.	39	30	1,000	S. E.	do.	1905	6	Apr. 24	Apr. 15	Apr. 8	.....	.....	Nov. 25	.....
105	do.	39	30	1,000	S. E.	do.	1906	7	Apr. 24	Apr. 26	Apr. 17	.....	.....	Oct. 10	.....
105	do.	39	30	1,000	S. E.	do.	1907	8	Apr. 6	May 2	Mar. 27	.....	.....	do.	.....
106	do.	40	15	850	S. E.	Clay	1902	4	Apr. 28	Apr. 26	Apr. 19	.....	.....	Oct. 13	.....
106	do.	40	15	850	S. E.	do.	1903	5	Apr. 18	Apr. 24	Apr. 26	.....	.....	.....	.....
106	do.	40	15	850	S. E.	do.	1904	6	May 6	May 11	Apr. 27	.....	.....	.....	.....
106	do.	40	15	850	S. E.	do.	1906	8	May 6	May 2	Apr. 18	.....	.....	May 9	.....
106	do.	40	15	850	S. E.	do.	1906	8	Apr. 26	May 2	Apr. 27	.....	.....	May 9	.....
108	do.	40	30	780	Level.	Clay loam.	1903	6	Apr. 22	Apr. 26	Apr. 13	.....	.....	Sept. 18	.....

4	Arkansas	34	30	1 250	E.	Sandy loam.	1907	8	Mar. 22	Mar. 27	Mar. 2	Apr. 15	Nov. 10	
17	Oklahoma	53	15	1 250	SE.	Clay loam.	1902	8	Apr. 17	Apr. 19	Mar. 28	Apr. 15	Nov. 9	
14	do.	33	30	1 250	N.	Sandy loam.	1904	12	Apr. 20	Apr. 1	Mar. 26	Mar. 13	Oct. 1	Dec. —
38	Arkansas	36	15	1 250	S.	do.	1904	8	Apr. 10	Apr. 15	Mar. 1	Apr. 20	Oct. 20	
61	Missouri	36	30	1 250	SE.	Black loam.	1903	7	Apr. 5	Apr. 25	May 1	Apr. 7	Sept. 20	
62	do.	36	30	1 200	All.	do.	1904	8	do.	Apr. 25	May 1	Apr. 7	Sept. 10	Sept. 10
62	do.	36	30	1 200	All.	do.	1903	9	Apr. 16	Apr. 22	Apr. 15	Apr. 6	Oct. 25	Spring.
62	do.	36	30	1 200	All.	do.	1906	10	Apr. 17	Apr. 22	Apr. 6	do.	Sept. 30	Nov.
63	do.	36	30	1 250	S.	Clay loam.	1902	6	Apr. 10	Apr. 20	Apr. 10	do.	Oct. 10	Dec.
64	do.	37	0	1 350	All.	Gravel loam.	1903	6	Apr. 17	Apr. 22	Apr. 8	do.	Sept. 25	
68	do.	37	0	1 350	All.	do.	1904	7	Apr. 24	Apr. 14	Apr. 30	Apr. 8	Oct. 28	
71	do.	37	0	1 250	N.	Clay	1907	9	Apr. 7	Mar. 27	May 13	Apr. 12	Oct. 28	
78	do.	37	15	1 250	All.	Clay loam.	1903	9	Apr. 8	Apr. 14	May 1	Apr. 10	Nov. 13	
86	do.	38	0	1 000	E.	Clay	1905	9	Apr. 9	Apr. 14	May 12	Apr. 7	Oct. 11	Nov.
90	do.	38	15	850	Level.	Black loam.	1907	12	Apr. 29	Apr. 4	May 12	Apr. 24	Oct. 13	Jan.
93	do.	38	30	540	All.	Clay loam.	1904	8	Apr. 29	May 3	May 2	Apr. 12	Oct. 23	
96	do.	38	45			do.	1907	10	Apr. 29	Mar. 30	May 4	Apr. 2	Oct. 18	
97	do.	39	0	700	W.	Clay	1903	8	Apr. 13	Apr. 15	May 1	Apr. 2	Oct. 18	
97	do.	39	0	700	W.	do.	1904	9	Apr. 9	May 4	Apr. 25	Apr. 23	Oct. 23	
97	do.	39	0	700	W.	do.	1906	10	Apr. 29	Apr. 20	Apr. 18	Apr. 7	Oct. 21	
97	do.	39	0	700	W.	do.	1906	11	Apr. 23	Apr. 28	May 9	Apr. 19	Oct. 10	Sept. 19
97	do.	39	0	700	W.	do.	1907	12	Apr. 23	Apr. 10	May 9	Apr. 28	Oct. 12	
99	do.	39	15	800	All.	do.	1906	12	Apr. 17	Apr. 24	May 9	Apr. 7	Nov. 1	Jan.

TABLE VIII.—*Phenological records of peaches.*

CHAMPION.

Ob- serv- er's No.	State.	Ap- proxi- mate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date full bloom.	Date full bloom.	Date last spring frost.	Date last buds begin to open.	Date terminal buds begin to form.	Date first picking.	Date last picking.	Date first fall frost.
2	Arkansas	34 15	900	S.	Sandy	1907	Yrs. 3	Mar. 7	Mar. 15	Feb. 10	Mar. 18		July 1	July 18	Nov. 1
27	Oklahoma	36 0	1,300	N.W.	Clay loam	1902	4	Mar. 26	Mar. 8	Apr. 10	Mar. 10		July 1	July 18	Nov. 1
28	do.	36 0	800	Level	Sandy loam	1907	4	Feb. 20	Mar. 1	Apr. 10	Mar. 10		July 1	July 18	Nov. 1
38	Arkansas	36 15	1,250	S.	do.	1904	4	Mar. 20	Mar. 8	Apr. 10	Mar. 10		July 1	July 18	Nov. 1
46	Arkansas	36 15	1,100	W.E.	do.	1906	3	Apr. 14	Apr. 22	May 3	Apr. 25	June —	Aug. 12	Aug. 18	Oct. 11
46	do.	36 15	1,100	W.E.	do.	1907	4	Apr. 14	Apr. 22	May 3	Apr. 25	June —	Aug. 12	Aug. 18	Oct. 11
60	do.	36 30	1,400	W.	do.	1907	6	Mar. 31	Apr. 7	May 1	Mar. 26	Sept. 1	Oct. 2	Oct. 2	Nov. 1
73	Missouri	37 0	1,000	W.	do.	1903	6	Mar. 31	Apr. 7	May 1	Mar. 26	Sept. 1	Oct. 2	Oct. 2	Nov. 1
75	do.	37 15	900	Level	Black loam	1904	3	Apr. 8	Apr. 11	May 2	Apr. 12		Oct. 13	Oct. 13	Nov. 1
75	do.	37 15	900	Level	do.	1906	5	Apr. 8	Apr. 11	May 2	Apr. 12		Oct. 13	Oct. 13	Nov. 1
75	do.	37 15	900	Level	do.	1907	6	Mar. 18	Mar. 20	Apr. 13	Apr. 14	Aug. 14	Sept. 5	Sept. 5	Oct. 23
79	do.	37 15	1,300	Level	do.	1907	12	Apr. 25	May 1	Apr. 18	Apr. 14	Aug. 17	Aug. 24	Aug. 24	Oct. 21
97	do.	39 0	700	S.	Clay	1904	6	Apr. 25	May 1	Apr. 18	Apr. 14	Aug. 17	Aug. 24	Aug. 24	Oct. 10
97	do.	39 0	700	S.	do.	1905	8	Apr. 13	Apr. 20	May 4	Apr. 15	Aug. 8	Aug. 12	Aug. 12	Oct. 12
97	do.	39 0	700	S.	do.	1906	9	Apr. 13	Apr. 20	May 4	Apr. 15	Aug. 8	Aug. 12	Aug. 12	Oct. 12
97	do.	39 0	700	S.	do.	1907	9	Apr. 13	Apr. 20	May 4	Apr. 15	Aug. 8	Aug. 12	Aug. 12	Oct. 12
99	do.	39 15	800	E.W.	do.	1903	7	Apr. 16	Apr. 20	May 2	Mar. 29	Sept. 10	Aug. 1	Aug. 20	Nov. 1
101	do.	39 15	466	S.	Sandy loam	1907	7	Apr. 25	Apr. 25	May 2	Mar. 29	Sept. 10	Aug. 10	Aug. 15	Oct. 25
106	do.	39 15	850	N.E.	Clay	1900	5	Apr. 19	Apr. 22	May 9	Apr. 20		Aug. 21	Aug. 27	Oct. 9

EARLY CRAWFORD.

1	Arkansas	33 45	400	Level	Sandy clay	1906	3 to 5	Mar. 20	Mar. 24	Mar. 20	Mar. 22		July —	July 31	Oct. 10
8	Oklahoma	35 15	1,028	S.	Clay loam	1906	4	Mar. 25	Apr. 2	Mar. 2	Mar. 3		July 17	July 31	Oct. 10
11	Arkansas	35 15	1,500	N.S.	Clay loam	1906	6	Mar. 20	Mar. 23	May 2	Mar. 3		July 10	July 31	Oct. 10
14	Oklahoma	35 15	1,050	SW.	Sandy loam	1903	7	Mar. 31	Apr. 2	May 2	Apr. 6		July 10	July 25	Nov. 26
16	Arkansas	35 30	1,100	W.	do.	1902	4	Mar. 18	Mar. 25	Feb. —	Mar. 12	Aug. 15	July 10	July 25	Nov. 26
17	do.	35 30	1,250	W.	do.	1904	9	Mar. 20	Mar. 15	do.	Mar. 5		July 10	July 25	Nov. 26
22	do.	35 45	992	S.	do.	1904	9	Mar. 20	Mar. 15	do.	Mar. 5		July 10	July 25	Nov. 26
27	do.	36 0	1,300	N.W.	Clay loam	1902	8	Mar. 23	Apr. 4	do.	Mar. 5		July 10	July 25	Nov. 26
35	Arkansas	36 15	1,200	N.	do.	1907	8	Mar. 23	Apr. 4	May 15	Mar. 14	July 20	Aug. 2	Aug. 2	Nov. 10
37	do.	36 15	1,250	W.	do.	1907	8	Mar. 12	Mar. 14	Apr. 13	Mar. 21	June 28	June 27	June 27	Oct. 19
40	do.	36 15	1,300	S.	Clay loam	1904	6	Mar. 18	Mar. 20	Apr. 13	Mar. 21	June 28	July 20	Aug. 1	Oct. 19
51	do.	36 30	1,300	N.	Chert	1907	8	Mar. 15	Mar. 21	Apr. 12	Mar. 25	July 10	Aug. 1	Aug. 15	Nov. 27
55	do.	36 30	1,300	N.	Sandy loam	1902	10	Apr. 3	Apr. 9	Mar. 19	Apr. 5	July 10	Aug. 10	Aug. 30	Oct. 10
56	do.	36 30	925	N.E.	Chert	1906	5	Apr. 4	Apr. 10	Apr. 17	Apr. 5		Aug. 10	Aug. 30	Oct. 10

62	Missouri.	36	30	1,200	N.	Black loam.	1904	7	Mar. 15	Mar. 20	Mar. 15	Mar. 14	June 6	July 25	Oct. 25
63	do.	36	30	1,200	N.	do.	1905	8	Mar. 31	Apr. 8	Apr. 20	Apr. 26	do.	do.	Oct. 2
73	do.	37	0	1,000	Level.	Sandy loam.	1903	8	Apr. 19	Apr. 23	May 1	Mar. 16	do.	do.	Oct. 12
81	do.	37	45	1,820	N.	Gravel loam.	1906	7	Apr. 21	Apr. 25	May 4	Apr. 18	Aug. 15	Aug. 15	Do.
84	do.	38	0	1,300	N.	Sandy loam.	1907	6	Apr. 21	Apr. 25	May 4	Apr. 18	Aug. 15	Aug. 15	Oct. 15
91	do.	38	15	400	N.	do.	1904	9	Apr. 21	Apr. 25	May 4	Apr. 18	Aug. 15	Aug. 15	Oct. 11
96	do.	38	45	800	S.	Light loam.	1907	9	Apr. 8	Apr. 17	Early	Apr. 10	June 20	Aug. 25	Oct. 8
95	do.	38	45	800	S.	do.	1906	10	Apr. 12	Apr. 15	Apr. 3	Apr. 15	June 4	Aug. 20	Oct. 11
95	do.	38	45	800	S.	do.	1906	11	Apr. 25	Apr. 19	May 2	Apr. 15	June 20	Aug. 25	Oct. 20
95	do.	38	45	800	S.	do.	1907	12	Apr. 25	Apr. 27	May 2	Apr. 14	June 25	Aug. 25	Oct. 21
97	do.	39	0	700	S.	Clay.	1905	7	Apr. 12	Apr. 18	Apr. 18	Mar. 27	Aug. 10	Aug. 28	Oct. 10
97	do.	39	0	700	S.	do.	1906	8	Apr. 23	Apr. 19	May 9	Apr. 18	Sept. 3	Aug. 16	Oct. 12
97	do.	39	0	700	S.	do.	1907	9	Apr. 23	Mar. 27	May 4	Apr. 26	Sept. 10	Aug. 16	Oct. 25
101	do.	39	15	468	S.	Sandy loam.	1907	7	Apr. 25	Mar. 29	May 2	Mar. 29	Aug. 1	Aug. 16	Oct. 10
103	do.	39	30	850	Level.	Black loam.	1906	3	Apr. 25	May 4	May 9	May 2	Aug. 1	Aug. 16	Oct. 25
103	do.	39	30	850	Level.	do.	1907	4	Mar. 26	Apr. 2	May 4	Mar. 24	July 25	Aug. 16	Oct. 13

ELBERTA.

1	Arkansas.	33	45	400	Level.	Sandy clay.	1905	3 to 5	Mar. 20	Mar. 24	Mar. 22	Mar. 22	July 14	July 24	Nov. 10
2	do.	34	15	600	S.	Sandy loam.	1907	3	Mar. 4	Mar. 10	Mar. 16	Mar. 16	July 14	July 24	Nov. 10
3	do.	34	15	1,000	S.	Clay loam.	1907	4	Mar. 4	Mar. 10	Mar. 16	Mar. 16	July 14	July 24	Nov. 10
4	do.	34	30	1,250	N.W.	Sandy loam.	1907	5	Mar. 4	Mar. 10	Mar. 16	Mar. 16	July 14	July 24	Nov. 10
5	do.	34	30	1,350	N.W.	do.	1904	6	Mar. 10	Mar. 12	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
6	do.	34	30	1,350	N.W.	do.	1904	6	Mar. 10	Mar. 12	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
7	do.	34	30	1,350	N.W.	do.	1904	6	Mar. 10	Mar. 12	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
8	Oklahoma.	35	15	1,025	S.	Clay loam.	1906	10	Mar. 25	Apr. 25	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
11	Oklahoma.	35	15	1,250	N.S.	Sandy clay.	1905	10	Mar. 1	Mar. 25	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
13	Oklahoma.	35	15	1,050	N.E.	Sandy loam.	1905	10	Mar. 1	Mar. 25	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
14	do.	35	15	1,050	S.W.	do.	1907	8	Mar. 1	Mar. 25	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
15	do.	35	15	1,050	S.W.	do.	1907	8	Mar. 1	Mar. 25	Mar. 26	Mar. 16	July 14	July 24	Nov. 10
15	Arkansas.	35	30	365	S.	do.	1903	7	Mar. 30	Apr. 2	Apr. 6	Apr. 6	July 14	July 24	Nov. 10
15	do.	35	30	365	S.	do.	1904	4	Mar. 30	Apr. 2	Apr. 6	Apr. 6	July 14	July 24	Nov. 10
16	do.	35	30	1,000	N.W.	do.	1904	5	Mar. 14	Mar. 19	Mar. 22	Mar. 22	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1902	5	Mar. 22	Mar. 27	Mar. 30	Mar. 30	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1902	5	Mar. 22	Mar. 27	Mar. 30	Mar. 30	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1903	7	Mar. 14	Mar. 23	Mar. 30	Mar. 30	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1903	7	Mar. 14	Mar. 23	Mar. 30	Mar. 30	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1906	8	Mar. 28	Apr. 6	Apr. 3	do.	July 14	July 24	Nov. 10
16	do.	35	30	1,100	N.W.	do.	1907	9	Feb. 20	Mar. 16	Feb. 26	Feb. 26	July 14	July 24	Nov. 10
17	Oklahoma.	35	30	1,250	N.	do.	1904	6	Feb. 19	Mar. 16	Feb. 26	Feb. 26	July 14	July 24	Nov. 10
18	do.	35	30	1,250	N.	do.	1904	6	Feb. 19	Mar. 16	Feb. 26	Feb. 26	July 14	July 24	Nov. 10
19	do.	35	30	784	S.	do.	1906	7	Mar. 27	Apr. 9	Apr. 30	Mar. 24	July 14	July 24	Nov. 10
21	Arkansas.	35	45	1,000	N.W.	do.	1903	11	Mar. 27	Apr. 9	Apr. 30	Mar. 24	July 14	July 24	Nov. 10
22	do.	35	45	982	S.	do.	1904	9	Feb. 26	Mar. 21	Apr. 17	Mar. 24	July 14	July 24	Nov. 10
22	do.	36	0	1,850	Level.	Clay loam.	1904	9	Feb. 26	Mar. 21	Apr. 17	Mar. 24	July 14	July 24	Nov. 10
22	do.	36	0	1,850	Level.	do.	1905	9	Feb. 26	Mar. 21	Apr. 17	Mar. 24	July 14	July 24	Nov. 10
22	do.	36	0	1,850	Level.	do.	1906	10	Apr. 9	Apr. 14	Feb. 5	Feb. 5	July 14	July 24	Nov. 10
22	do.	36	0	1,850	Level.	do.	1906	10	Apr. 9	Apr. 14	Feb. 5	Feb. 5	July 14	July 24	Nov. 10
26	do.	36	0	1,850	Level.	do.	1907	11	Apr. 9	Apr. 14	Feb. 5	Feb. 5	July 14	July 24	Nov. 10
26	do.	36	0	1,450	S.W.	Sandy loam.	1906	11	Apr. 9	Apr. 14	Feb. 5	Feb. 5	July 14	July 24	Nov. 10
26	do.	36	0	1,450	S.W.	do.	1907	9	Mar. 14	Apr. 10	May 9	Apr. 4	Sept. 10	Sept. 12	Oct. 15
27	Oklahoma.	36	0	1,300	N.W.	Clay loam.	1902	9	Mar. 27	Apr. 7	Apr. 10	Mar. 19	Sept. 10	Sept. 12	Oct. 15

TABLE VIII.—*Phenological records of peaches—Continued.*

ELBERTA—Continued.

Ob- serv- er's No.	State.	Ap- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date pick- ing.	Date last pick- ing.	Date first fall frost.
28	Oklahoma.	36 0	Feet. 800	Level.	Sandy loam.	1907	Yrs. 15	Mar. 4	Mar. 16	Feb. 10	Mar. 15	June 20	Aug. 4	Aug. 30	Nov. 1
29	Arkansas.	36 0	1,650	Level.	do.	1906	5	Apr. 18	Apr. 8	Mar. 22	Apr. 1	June 20	Aug. 10	Aug. 20	Sept. 27
30	Arkansas.	36 15	1,000	S. E.	do.	1903	3	Mar. 18	Mar. 28	Mar. 15	Mar. 25	June 20	Aug. 10	Aug. 20	Oct. 20
31	Oklahoma.	36 15	1,350	Level.	Clay loam.	1904	6	Mar. 7	Mar. 15	Apr. 15	Mar. 15	June 20	Aug. 15	Aug. 25	Oct. 20
32	Arkansas.	36 15	1,300	W.	do.	1907	3	Mar. 7	Mar. 15	Apr. 15	Mar. 15	June 20	Aug. 15	Aug. 25	Oct. 20
33	do.	36 15	1,400	S.	Clay.	1906	15	Apr. 1	Apr. 15	May 14	Feb. 15	June 20	Aug. 1	Aug. 15	Oct. 10
34	do.	36 15	1,400	S.	do.	1907	16	Mar. 3	Mar. 11	May 14	Feb. 15	June 20	Aug. 1	Aug. 15	Oct. 10
35	do.	36 15	1,200	N.	Clay loam.	1907	8	Mar. 3	Mar. 11	May 14	Feb. 15	June 20	Aug. 1	Aug. 15	Oct. 10
36	do.	36 15	1,250	W. S.	Gravel.	1907	4	Mar. 14	Mar. 14	Apr. 28	Mar. 24	June 30	July 29	Aug. 10	Nov. 10
37	do.	36 15	1,250	W. S.	Sandy loam.	1904	2	Mar. 16	Mar. 14	Apr. 28	Mar. 24	June 30	July 29	Aug. 10	Nov. 10
38	do.	36 15	1,250	S.	do.	1906	2	Apr. 3	Apr. 6	May 11	Apr. 1	June 30	July 29	Aug. 10	Nov. 10
39	do.	36 15	1,265	S.	Gravel loam.	1902	2	Apr. 3	Apr. 6	May 11	Apr. 1	June 30	July 29	Aug. 10	Nov. 10
40	do.	36 15	1,400	W.	Sandy loam.	1906	3	Apr. 4	Apr. 6	May 11	Apr. 1	June 30	July 29	Aug. 10	Nov. 10
41	do.	36 15	1,400	W.	Chert.	1902	10	Mar. 28	Apr. 6	May 11	Apr. 1	June 30	July 29	Aug. 10	Nov. 10
42	do.	36 15	1,345	W.	do.	1902	5	do.	do.	do.	do.	do.	do.	do.	do.
43	do.	36 30	1,500	E. W.	do.	1902	3	Mar. 29	do.	do.	do.	do.	do.	do.	do.
44	do.	36 30	1,500	SW.	do.	1902	3	Mar. 29	do.	do.	do.	do.	do.	do.	do.
45	do.	36 30	1,500	N.	do.	1902	8	Apr. 4	Apr. 22	Mar. 12	Apr. 9	June 6	July 26	Aug. 18	Oct. 20
46	do.	36 30	1,500	N.	do.	1907	5	Apr. 18	Apr. 22	Mar. 12	Apr. 9	June 6	July 26	Aug. 18	Oct. 20
47	do.	36 30	1,575	N.	do.	1902	8	Mar. 30	Apr. 3	Mar. 31	Apr. 6	June 6	July 26	Aug. 18	Oct. 20
48	do.	36 30	1,300	W.	do.	1902	10	Apr. 3	Apr. 9	Mar. 19	Apr. 6	June 6	July 26	Aug. 18	Oct. 20
49	do.	36 30	1,300	N. E.	Sandy loam.	1906	5	Apr. 4	Apr. 9	Mar. 19	Apr. 6	June 6	July 26	Aug. 18	Oct. 20
50	do.	36 30	1,400	W.	Sandy loam.	1907	5	Apr. 4	Apr. 9	Mar. 19	Apr. 6	June 6	July 26	Aug. 18	Oct. 20
51	do.	36 30	1,200	N.	Black loam.	1904	10	Apr. 18	Apr. 21	Mar. 20	Mar. 15	June 6	July 26	Aug. 18	Oct. 20
52	Missouri.	36 30	1,200	N.	do.	1905	10	do.	do.	do.	do.	do.	do.	do.	do.
53	do.	36 30	1,250	SW.	Clay loam.	1902	3	Apr. 3	Apr. 12	Mar. 13	Mar. 1	June 6	July 26	Aug. 18	Oct. 20
54	do.	36 45	900	All.	Chert.	1907	5	Mar. 5	Mar. 17	Apr. 13	Mar. 1	June 6	July 26	Aug. 18	Oct. 20
55	do.	36 45	950	All.	do.	1902	3	Mar. 5	Mar. 17	Apr. 13	Mar. 1	June 6	July 26	Aug. 18	Oct. 20
56	Oklahoma.	36 45	950	All.	do.	1902	3	Mar. 5	Mar. 17	Apr. 13	Mar. 1	June 6	July 26	Aug. 18	Oct. 20
57	do.	36 45	1,482	S. E.	Clay loam.	1907	4	Apr. 5	Apr. 13	Mar. 14	Apr. 15	July 10	Aug. 5	Aug. 23	Nov. 21
58	do.	37 0	1,350	E. W.	Clay.	1907	4	Apr. 12	Apr. 18	Mar. 14	Apr. 15	July 10	Aug. 5	Aug. 23	Nov. 21
59	do.	37 0	1,350	All.	Gravel loam.	1904	6	Mar. 16	Apr. 21	Apr. 13	Mar. 4	Aug. 14	Aug. 15	Aug. 24	Oct. 2
60	do.	37 0	1,650	N. W.	Chert.	1903	8	Mar. 19	Apr. 24	Apr. 13	Mar. 4	Aug. 14	Aug. 15	Aug. 24	Oct. 2
61	do.	37 0	1,000	N. W.	do.	1907	10	Mar. 31	Apr. 7	May 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
62	do.	37 15	960	Level.	Black loam.	1906	5	Apr. 8	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
63	do.	37 15	960	SW.	do.	1907	6	Apr. 8	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
64	do.	37 15	1,300	SW.	Clay loam.	1902	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
65	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
66	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
67	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
68	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
69	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
70	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
71	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
72	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
73	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
74	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
75	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
76	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
77	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
78	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
79	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2
80	do.	37 15	1,300	SW.	do.	1904	6	Apr. 18	Apr. 20	Apr. 17	Apr. 10	July 15	Aug. 15	Aug. 24	Oct. 2

70	do.	1,300	Level.	Black loam.	1907	5	Mar. 17	Mar. 20	Apr. 13	Apr. 2	May 17	Aug. 13	Aug. 19	Oct. 20
80	do.	600	N.	Clay	1907	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
81	do.	820	Level.	Sandy loam.	1906	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
82	do.	1,100	N.W.	Clay	1907	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
83	do.	1,300	N.	Gravel loam.	1907	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
84	do.	1,300	N.	Clay	1906	8	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
87	do.	1,000	Level.	Clay	1906	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
89	do.	800	N.	Gravel loam.	1907	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
90	do.	400	N.	Sandy loam.	1906	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
91	do.	400	N.	do.	1907	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
92	do.	400	S.E.	do.	1906	12	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
92	do.	550	S.E.	do.	1906	13	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
92	do.	550	S.E.	do.	1907	14	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
93	do.	800	S.	Clay loam.	1904	4	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
93	do.	800	S.	Light loam.	1904	7	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
95	do.	800	S.	do.	1905	8	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
95	do.	800	S.	do.	1906	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
97	do.	700	S.	Clay	1904	6	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
97	do.	700	S.	do.	1905	7	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
97	do.	700	S.	do.	1906	8	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
97	do.	700	S.	do.	1907	9	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
99	do.	800	E.W.	do.	1906	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
101	do.	466	S.	Sandy loam.	1906	5	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
103	do.	850	Level.	Black loam.	1906	3	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
103	do.	850	Level.	do.	1907	4	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20
106	do.	850	N., E.	Clay	1906	10	Mar. 17	Mar. 27	Apr. 13	Apr. 1	May 17	Aug. 13	Aug. 19	Oct. 20

FAMILY FAVORITE.

14	Oklahoma	1,050	S.W.	Clay loam.	1902	7	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
20	do.	1,400	E.	Sandy loam.	1905	10	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
26	do.	1,450	S.W.	do.	1906	10	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
27	Oklahoma	1,200	N.W.	Clay loam.	1902	4	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
43	Missouri	1,250	S.W.	do.	1902	7	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
67	do.	1,350	E., W.	Clay	1904	4	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
75	do.	900	Level.	Black loam.	1907	3	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
75	do.	900	Level.	do.	1906	5	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
75	do.	900	Level.	do.	1907	6	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
95	do.	700	S.	Clay	1904	10	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
97	do.	700	S.	do.	1905	11	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
97	do.	700	S.	do.	1906	12	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6
97	do.	700	S.	do.	1907	13	Mar. 17	Mar. 20	Apr. 13	Apr. 8	June 1	July 25	Aug. 4	Oct. 6

1 Winterkilled.

TABLE VIII.—*Phenological records of peaches—Continued.*

SALWAY—Continued.

Ob- serv- er's No.	State.	AP- prox- imate lati- tude.	Eleva- tion.	Slope.	Soil.	Year.	Age of tree.	Date first bloom.	Date full bloom.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date first pick- ing.	Date last pick- ing.	Date first fall frost.
63	Missouri	36 30	Feet. 1,250	SW.	Clay loam.	1902	Yrs. 5	Apr. 8	Apr. 14	Apr. 7	July 10	Aug. 28	Sept. 8	Nov. 21
65	do.	36 45	950		Chert.	1902	4	Apr. 6	Apr. 13	Apr. 15	Sept. 10	Sept. 20	Oct. 7	Oct. 28
68	do.	37 0	1,350		Gravel loam	1904	6	Mar. 21	Apr. 6	Apr. 8		Sept. 17	Sept. 20	Oct. 12
84	do.	38 0	1,300	N.	do.	1907	3	Apr. 28	May 2	Mar. 19				Oct. 23
83	do.	38 30	580	S.	Clay loam.	1904	10	Apr. 28	May 2	Apr. 2	June 16	Sept. 20	Oct. 5	Oct. 15
95	do.	38 45	800	S.	Light loam.	1904	10	Apr. 12	Apr. 15					Oct. 21
97	do.	39 0	700	S.	Clay.	1905	7	Apr. 8	Mar. 27	Mar. 31	Sept. 23	Oct. 1	Oct. 10	Oct. 12
97	do.	39 0	700	S.	do.	1907	9	Apr. 26	Apr. 30	Mar. 26	Sept. 6			Nov. 1
99	do.	39 15	800	E., W.	do.	1906	8	Apr. 26	Apr. 30	May 9				

SMOCK.

17	Oklahoma	35 30	1,250	W.	Sandy loam.	1904		Mar. 20	Apr. 1	Mar. 26				Nov. 9
38	Arkansas	36 15	1,250	S.	do.	1904		do.	Apr. 8	Apr. 10		Sept. 3	Sept. 9	Nov. 23
39	do.	36 15	1,250	S.	Gravel loam.	1904	5	Apr. 2	Apr. 7	Mar. 20				
40	Oklahoma	36 15	1,100	W., E.	Sandy loam.	1906	3	Apr. 15	Apr. 20	May 3				Oct. 11
43	do.	36 30	1,100	W., E.	do.	1907	4	Mar. 17	Apr. 3	Apr. 8	June 6			Oct. 20
62	Missouri	36 30	1,250	SW.	Black loam.	1905	5	Mar. 7	Apr. 14	Apr. 20	June 6			
63	do.	36 30	1,250	SW.	Clay loam.	1906	5	Apr. 10	Apr. 12	Apr. 13	Sept. 1	Aug. 15	Aug. 28	
61	do.	37 45	550	SE.	Sandy loam.	1906	12	Apr. 10	Apr. 16	Apr. 13	Sept. 1	Sept. 20	Sept. 25	Oct. 11
62	do.	37 30	550	SE.	do.	1907	16	Apr. 10	Apr. 16	Apr. 13	Aug. 30	Sept. 1	Sept. 25	Oct. 11
65	do.	38 0	800	S.	do.	1907	16	Apr. 10	Apr. 16	Apr. 13	Aug. 30	Sept. 1	Sept. 25	Oct. 11
66	do.	38 45	800	S.	Light loam.	1906	11	Apr. 12	Apr. 14	Apr. 2	June 15	Sept. 13	Sept. 25	Oct. 11
65	do.	38 45	800	S.	do.	1906	12	Apr. 15	Apr. 20	Apr. 2	June 15	Sept. 13	Sept. 25	Oct. 11
66	do.	39 0	700	S.	do.	1906	12	Apr. 15	Apr. 20	Apr. 2	June 15	Sept. 13	Sept. 25	Oct. 11
67	do.	39 0	700	S.	Clay.	1904	6	Apr. 26	Apr. 30	Apr. 18	Oct. 5	Sept. 23	Sept. 28	Oct. 21
67	do.	39 0	700	S.	do.	1906	7	Apr. 13	Apr. 20	Apr. 18	Oct. 5	Sept. 23	Sept. 28	Oct. 21
67	do.	39 0	700	S.	do.	1907	8	Mar. 23	Apr. 30	Apr. 18	Oct. 5	Sept. 23	Sept. 28	Oct. 21
67	do.	39 0	700	S.	do.	1907	9	Mar. 23	Apr. 30	Apr. 18	Oct. 5	Sept. 23	Sept. 28	Oct. 21
69	do.	39 15	800	E., W.	do.	1906	3	Apr. 20	Apr. 23	May 9	Aug. 28	Sept. 20	Sept. 25	Nov. 1

DESCRIPTION OF PLATES.

PLATE I. Sketch map of the Ozark region. The counties in Missouri, Arkansas, and Oklahoma which comprise the principal portion of the Ozark uplift are indicated. The 500-foot contour lines are given; also the location of a number of the more important towns.

PLATE II. Trees of the Ada Red apple in northwestern Arkansas. Fig. 1.—The original tree of the variety, photographed July 26, 1907. The tree has constantly been in a much-neglected condition, hence its relatively small size. Fig. 2.—A tree about 5 years of age, showing the tendency to an upright habit of growth. Trees of the same variety at about the age of 10 years that had produced considerable fruit had become more spreading.

PLATE III. Trees of the Arkansas apple in northwestern Arkansas. Fig. 1.—The original tree of the variety, photographed August 25, 1906. The tree was then about 75 years old and measured approximately 8 feet in circumference at about 2 feet from the ground; the topmost branches were dead and the main limbs had been broken off. This tree is illustrated in Bulletin 49 of the Arkansas Agricultural Experiment Station from a photograph taken in the fall of 1897. It showed no dead limbs at that time and was apparently in good condition. Fig. 2.—A well-pruned tree at the age of 10 years, showing the symmetrical and vigorous habit of growth.

PLATE IV. Trees of the Collins apple in northwestern Arkansas. Fig. 1.—The original tree of the variety, photographed August 24, 1906. The tree was then about 40 years old. For many years it stood in an open field and was given little or no attention. A young orchard now surrounds it. Fig. 2.—A tree at about 12 years of age, showing the habit of growth when proper pruning has been neglected.

PLATE V. Orchards in the Ozark region. Fig. 1.—A block of 5-year-old trees of the Gano apple. These trees are headed higher than is usual in orchards in this region. The central leader was removed when the trees were planted, and the heads grew from a relatively small number of limbs—usually 4 to 6. (Compare fig. 6, p. 57.) Fig. 2.—A young peach orchard interplanted with strawberries, illustrating a common practice in the sections in which strawberries are extensively grown, during the years when an orchard is coming into bearing.

PLATE VI. A peach orchard of the Elberta variety near Van Buren, Ark., photographed July 24, 1907. This orchard is typical of the better kept ones in this section. Normally the foliage would be more dense, but in this case it had been injured considerably by a spray mixture.



FIG. 1.—THE ORIGINAL TREE OF THE VARIETY,
JULY 26, 1907.



FIG. 2.—A TREE ABOUT 5 YEARS OF AGE

TREES OF THE ADA RED APPLE IN NORTHWESTERN ARKANSAS.



FIG. 1.—THE ORIGINAL TREE OF THE VARIETY,
AUGUST 25, 1906.



FIG. 2.—A WELL-PRUNED TREE AT THE AGE OF 10 YEARS.

TREES OF THE ARKANSAS APPLE IN NORTHWESTERN ARKANSAS.



FIG. 1.—THE ORIGINAL TREE OF THE VARIETY, AUGUST 24, 1906.



FIG. 2.—A TREE ABOUT 12 YEARS OF AGE.
TREES OF THE COLLINS APPLE IN NORTHWESTERN ARKANSAS.



FIG. 1.—A BLOCK OF 5-YEAR-OLD TREES OF THE GANO APPLE.



FIG. 2.—A YOUNG PEACH ORCHARD INTERPLANTED WITH STRAWBERRIES.
ORCHARDS IN THE OZARK REGION.



A PEACH ORCHARD OF THE ELBERTA VARIETY NEAR VAN BUREN, ARK.
(Photographed July 24, 1907.)

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[Among varietal names, synonyms are distinguished by being printed in *italic type*.]

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Issued March 22, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 276.

B. T. GALLOWAY, *Chief of Bureau.*

THE UTILIZATION OF WASTE RAISIN SEEDS.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, BEVERLY T. GALLOWAY.

Assistant Chief of Bureau, WILLIAM A. TAYLOR.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 18, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 276 of the series of this Bureau the accompanying manuscript entitled "The Utilization of Waste Raisin Seeds," by Mr. Frank Rabak, Chemical Biologist, submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

This investigation deals with the utilization of a by-product of an agricultural industry which has hitherto been disregarded. It has been shown that the seeds removed from raisins yield technically useful products, which by their value fully justify the expense involved in separating them. It is believed that this situation is typical of many so-called agricultural waste products which are at present not fully utilized.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE UTILIZATION OF WASTE RAISIN SEEDS.

INTRODUCTION.

In the canning and packing operations of the fruit industry in the United States certain by-products almost invariably result, many of which, because of lack of utilization, become in the true sense waste products. In the commercial canning and drying of peaches, apricots, and prunes the pits were formerly to a large extent waste material. Through an investigation recently made in the Bureau of Plant Industry,¹ however, valuable uses were discovered for this material, and as a consequence it is now used in the manufacture of many important commercial products. In the raisin-seeding industry, which within recent years has grown to such proportions in the grape-producing sections of California, vast quantities of seed accumulate annually (fig. 1). Thus far this material has been practically wasted, and it was with the object in view of preparing products of commercial value from these waste raisin seeds that the investigation herein described was undertaken.

ACCUMULATION AND PRESENT DISPOSAL OF RAISIN SEEDS.

Some idea may be gained of the vast accumulation of raisin seeds when it is considered that 30,000 to 40,000 tons of raisins are seeded annually. By actual test it has been found that 9.75 or approximately 10 per cent of the fruit consists of seeds. There should therefore be in the neighborhood of 3,000 to 4,000 tons of this material available each year. Within the past few years the matter of utilizing waste raisin seeds has been receiving some attention from the producers, but thus far with little success. From the information at hand it appears that a brandy has been made by fermenting the sugary matter which adheres to the seeds. A high-proof alcohol has also been distilled after the fermentation. It has been reported that some fixed oil has been obtained, but whether or not this has proved successful is not definitely known.

In this connection it seems desirable to mention also the possible utilization of grape seeds, of which there is a large accumulation from the residues of wineries and grape-juice factories in this country.

¹ Rabak, F. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. Bulletin 133, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

The utilization of these seeds has received considerable attention in the past from foreign wine growers, but with only a limited degree of success. This may be due to the fact that only one constituent, namely, the fixed oil, seemed to be made use of. In 1827 Fontenele¹ stated that it had long been known that grape seeds contain a fixed oil, but that in France there was lack of knowledge with regard to its extraction. For several years prior to this time the oil had been used in Italy to a certain extent for illuminating purposes, rivaling olive oil from the standpoint of light, clear flame, and lack of odor. This was brought to the attention of agriculturists for the reason that the



FIG. 1.—Waste raisin seeds.

seeds were being lost to them. According to Fontenele 60 pounds of the seeds produced 6 pounds of oil.

In 1828 Schübler² stated that for a long time the seeds of grapes had been utilized in the southern regions of Europe for their oil, which was used as an edible oil. It was said that the oil possessed illuminating properties, burning slowly in common lamps, being similar in this respect to poppy-seed oil, tobacco-seed oil, and the slow-burning rapeseed oil. The following year it was reported that the oil had been produced in a small way in Wurttemberg, but with no great

¹ Fontenele, J. Sur l'extraction de l'huile des pépins de raisins. *Journal de Chimie Médicale*, vol. 3, 1827, p. 66.

² Schübler, G. Untersuchungen über die fetten Oele Deutschlands in Beziehung auf ihre wichtigeren physischen Eigenschaften, 18. Oel der Weintraubenkerne, von *Vitis vinifera* L. *Journal für Technische und Ökonomische Chemie*, vol. 2, 1828, p. 364.

success.¹ In Wurttemberg alone at that time it was calculated that 340,000 pounds of grape seeds were lost annually.

According to Minutoli² the oil was said to be useful for soap-making purposes and when used in salad it was not without a pleasant taste.

The method employed for extracting the fixed oil consisted in separating the husks and stems from the seeds by drying and passing them through sieves.³ The dried seeds were ground to a meal, placed in a copper kettle, and one-third or one-fourth their weight of water added. Heat was applied and the mass was stirred continually to prevent the formation of lumps. When free fixed oil appeared upon pressure between the fingers, the mass was put into canvas bags and placed in an oil press. The cake was again treated in a similar manner and another quantity of oil produced. In this way from 10 to 20 per cent of oil was obtained from the seeds.

Marre⁴ has recently called attention to the need of reviving this industry and states that in France in the Departments of Gard, Hérault, Aude, and the Pyrenees-Orientales there are at least 28,000,000 hundredweight of grapes, or about 1,036,000 hundredweight of seeds, from which, provided a yield of 15 per cent of oil were obtained, there would result 155,000 hundredweight of oil, valued roughly at 11,655,000 francs.

According to Paris,⁵ wine residues consist of 25 to 30 per cent of stems, 50 to 60 per cent of skins, and 15 to 20 per cent of seeds, the total residue comprising about 15 to 25 per cent of the grapes. After extracting the oil the seeds contain 10.6 per cent of moisture, 9.12 per cent of crude protein, 4.2 per cent of crude fat, 45.2 per cent of crude fiber, 3.15 per cent of ash, and 27.6 per cent of nitrogen-free extractive matter, of which 11.5 per cent are carbohydrates and 12.4 per cent pentosans. The digestibility of the protein amounts to 70 per cent, fat 75 per cent, nitrogen-free extractive matter 85 per cent, and crude fiber 50 per cent. It is stated that the ash consists of 14.3 per cent of phosphorus pentoxid and 22.3 per cent of potassium oxid.

It has but recently been reported⁶ that grape-seed oil is an important product of the wine regions of France and Italy, where it is used as an edible oil and in the manufacture of soap. It is stated that 3 pounds of the oil will make 5 pounds of soap of good quality. The oil is extracted by hot or cold pressure or by solvents. On account of its high protein content the meal is said to be eaten by cattle with relish.

¹ Schübler, G. Darstellung des fetten Oels aus dem Kernen der Weintrauben. *Journal für Technische und Ökonomische Chemie*, vol. 5, 1829, p. 31.

² Minutoli. Bemerkung über die Anwendung der Traubenkerne zur Oelbereitung. *Journal für Technische und Ökonomische Chemie*, vol. 10, 1831, p. 352.

³ Oel aus Traubenskernen. *Dinger's Polytechnisches Journal*, vol. 148, 1858, p. 238.

⁴ Marre, F. L'huile des pépins de raisin. *Revue Générale de Chimie Pure et Appliquée*, vol. 14, 1911, p. 186.

⁵ Paris, G. I Vinaccioli. *Le Stazioni Sperimentali Agrarie Italiane*, vol. 44, 1911, fasc. 8-9, p. 669.

Grape-seed oil. *Pure Products*, vol. 8, 1912, p. 217.

EXAMINATION OF RAISIN SEEDS FOR COMMERCIAL PRODUCTS.

The successful and profitable utilization of raisin seeds will depend not only upon the preparation of the various products obtainable, but also upon the practical uses to which they can be put. The object of this paper is to show not only what products can be made from the seeds, but also to point out the various channels of trade into which they may go in order to serve as important practical commodities.

The first step in the process of examination was to make use of the sugary matter which adheres to the seeds as they come from the seeding machines (fig. 2). From this material a very desirable sirup



FIG. 2.—Raisin seeding machine in operation.

was prepared (fig. 3). The next step was to determine the quantity of fixed oil, since it is known that the seeds of practically all fruits contain fatty or fixed oil to a greater or less extent and that many such oils are important articles of commerce, entering into the manufacture of paints, varnishes, soaps, etc. (fig. 3). From the astringent taste of the seeds the presence of tannin was suspected, and since tannins are valuable articles of commerce a determination of the tannin content was next made (fig. 3). As a final product, after the extraction of the fixed oil and the tannin, the residue was analyzed for its possibilities as a stock food (fig. 3).

In the following pages each of the products mentioned is discussed separately in regard to methods of preparation, extraction, chemical

analysis, application in commerce, the approximate quantity available, and the probable value. The investigation of the seeds was taken up systematically, in order that every available constituent

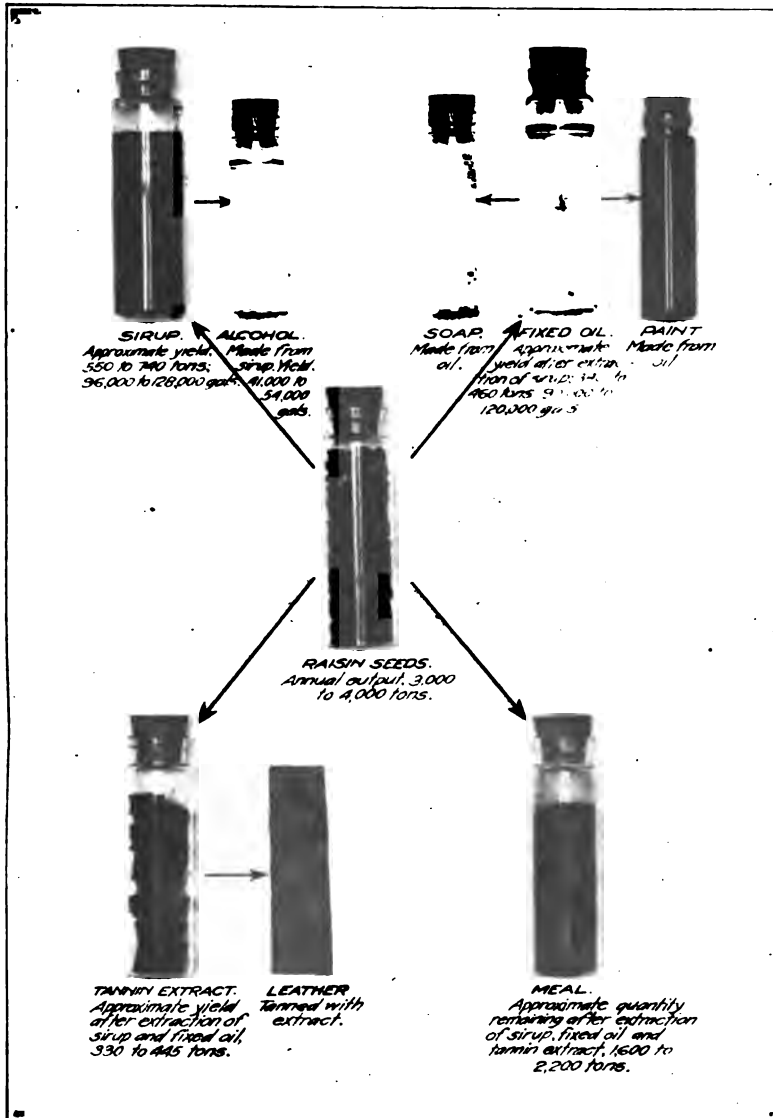


FIG. 3.—Commercial products from waste raisin seeds.

which is capable of being extracted practically might be given careful attention and that as many articles of commercial value as possible might be produced.

SIRUP.**PREPARATION.**

As the initial step in the process of utilizing the waste raisin seeds, the material, which consisted of a sticky mass of seeds and pulp, was washed with cold water to remove the adhering pulp. The solution thus obtained was distinctly sweet and it was thought it might be of value in the preparation of a sirup. It was therefore concentrated on a water bath, and a yield of 18.5 per cent of an agreeable sweet sirup was obtained, which possessed the characteristic raisin taste. As the material was received directly from the seeding machines it represented, so far as the writer is aware, the average condition of raisin seeds with respect to the amount of adhering sugary matter, and these figures may therefore be taken as the average percentage of available sirup. It is probable, however, that seasonal conditions have a direct influence on the sugar content of the fruit and also that the effectiveness of the machines in removing the pulp would affect the quantity of sirup obtainable, since in some instances much more pulp is left adhering to the seeds than in others.

PHYSICAL PROPERTIES.

The sirup had a consistency about equal to that of strained honey and was reddish brown in color. The specific gravity at 22° C. was found to be 1.384.

CHEMICAL EXAMINATION.**SUGARS.**

The percentage of sugars present was determined by volumetric assay with Fehling's solution. One gram of the sirup was found to reduce 122 cubic centimeters of Fehling's solution. The dextrose factor for Fehling's solution, previously ascertained, was 0.005. These results show, therefore, that 1 gram of the sirup contains 0.61 gram, or 61 per cent, of reducing sugars calculated as dextrose.

A weighed portion of the sirup was subsequently inverted by the addition of a few drops of hydrochloric acid and heating on a water bath for one-half hour. By this operation the cane sugar and perhaps other polysaccharids were inverted to monosaccharids. The total reducing sugars were then determined as glucose. The difference in the number of cubic centimeters of Fehling's solution required before and after inversion corresponds to the cane sugar in the sample. Two grams of the sirup after inversion required 12.4 cubic centimeters of Fehling's solution in excess of the amount required for dextrose. From the cane-sugar factor of Fehling's solution (0.00475) the total amount of cane sugar in the 2 grams of sirup was 0.0589 gram, which corresponds to 2.94 per cent of cane sugar.

ACIDS.

In connection with the intensely sweet taste of the sirup a slightly tart taste was noticeable, which was doubtless due to the presence of grape acids. The acidity was determined in terms of tartaric acid. Two grams of the sirup by titration with standard N/10 potassium-hydroxid solution required 2.85 cubic centimeters of alkali, which, from the tartaric-acid factor for decinormal alkali (0.007446), corresponds to 0.0212 gram of tartaric acid, or 1.06 per cent.

This analysis of the sirup indicates the composition only in a very general way as far as sugars and free acidity are concerned. Many factors may enter to vary the composition. The consistency of the sirup will have much to do with the percentage of sugars; the more the sirup is evaporated the higher will be the percentage of sugar, and vice versa.

PRODUCTION OF ALCOHOL.

As the sirup contains such a large quantity of fermentable sugar, the commercial production of alcohol from this by-product should be feasible. In order to determine the amount of alcohol capable of being fermented, 150 grams of the sirup were dissolved in about a quart of water, to which a teaspoonful of fresh yeast was added. The mixture was allowed to ferment for about 24 hours at a temperature of 30° C., or until the evolution of carbon dioxide ceased. After filtering the solution it was acidified with phosphoric acid to neutralize any volatile alkalis which may have been present. The solution was distilled over a direct flame until all of the alcohol was removed from the flask. After making alkaline with potassium-hydroxid solution to neutralize any volatile acids present and distilling, 90 cubic centimeters of alcohol were obtained. The specific gravity of the alcohol was 0.930 at 22° C., which corresponds to 42 per cent of absolute alcohol by weight. The total amount of dilute alcohol therefore contained 35.1 grams of absolute alcohol. Calculating from the amount of sirup used in the experiment, a total of 23.4 per cent of absolute alcohol can be obtained by fermentation of the sirup.

From these results it is estimated that the total amount of alcohol (calculated as absolute alcohol) capable of being manufactured from the sirup would approximate 130 to 170 tons. This quantity of absolute alcohol would represent about 140 to 184 tons of alcohol U. S. P. (190 proof), which corresponds to 41,176 to 54,117 gallons.

COMMERCIAL USES.

With its agreeable flavor and sweet fruity taste, the sirup from raisin seeds possesses qualities which should make it useful in the household and also in various commercial industries. For instance, in

the making of mincemeat, in which large quantities of raisins are ordinarily used, the sirup could be used to a certain extent at perhaps less expense, certainly with less labor, and still the peculiar and agreeable flavor of the raisins could be retained. For table use it would seem to be distinctly desirable, since the flavor and wholesomeness of the raisins are to a great extent retained. A prominent manufacturer of sirups for soda-fountain use has pronounced it to be a most excellent flavor for carbonated drinks, and it should find use in this direction.

The outlook, therefore, for creating a demand for this by-product is very promising.

AVAILABLE QUANTITY AND VALUE.

In view of its possible commercial uses, the question of the approximate quantity available and the value of the sirup is important. Since 3,000 to 4,000 tons of seeds are available annually from the seeded-raisin industry and since approximately 18.5 per cent of sirup is obtainable from this material, it follows that 555 to 740 tons could be manufactured yearly. This is the equivalent of 1,110,000 to 1,480,000 pounds, or, calculating from the specific gravity of the sirup, 96,522 to 128,696 gallons.

The value will, of course, depend largely upon the channels of trade into which it is directed. A conservative estimate, however, would place it at from \$30,000 to \$50,000 annually, provided a demand for the product is created in which its usefulness is assured, and it is not unreasonable to assume that some of the suggested uses will eventually build up a steady demand for this product.

FIXED OIL.

EXTRACTION AND PHYSICAL PROPERTIES.

After removing the sugary pulp, the seeds were screened, dried, and ground, and then extracted with ether in a continuous-extraction apparatus. A yield of about 14.5 per cent of a pale, golden-yellow oil was obtained, which possessed a slightly fatty odor with a bland, nutlike taste. The specific gravity at 24° C. was 0.9220 and the index of refraction at 25° C. was 1.4702.

CHEMICAL EXAMINATION.

FREE ACIDS.

The amount of free acids in the oil was ascertained by titrating a weighed quantity of the oil with alcoholic potassium hydroxid. One gram of the oil was found to require 1.25 milligrams of potassium hydroxid for neutralization, corresponding to 0.62 per cent of free acid calculated as oleic acid.

SAPONIFICATION VALUE.

As a measure of the glycerids of fatty acids, the saponification number (Koettstorfer number) was determined by heating a weighed quantity of the fixed oil with a definite volume of alcoholic potassium hydroxid and titrating back the excess of alkali with standard hydrochloric-acid solution. The saponification value, or the number of milligrams of potassium hydroxid required to saponify the fatty-acid glycerids in 1 gram of the oil, was found to be 188.

IODIN ABSORPTION.

The property of iodine absorption possessed by fixed oils is dependent upon the presence of unsaturated fatty acids or fatty-acid glycerids. It is a property of all unsaturated fatty acids to take up iodine by direct addition, the amount absorbed depending upon the nature of the unsaturated compounds or the number of double bonds they contain. Saturated fatty acids and their glycerids containing no double bonds do not possess this property. The iodine number is therefore an indication of the composition of a fixed oil as regards the content of unsaturated fatty acids and often determines the class of oils to which it belongs.

The iodine absorption of raisin-seed oil was determined in the usual manner, that is, by allowing iodine to react under the conditions directed¹ with a definite quality of oil and titrating the excess by means of standard sodium-thiosulphate solution. The iodine absorption (or Hübl's) number was found to be 131.

VOLATILE ACIDS.

It has been stated that fixed oils consist largely of glycerids of fatty acids. The fatty acids in combination with glycerin may be either volatile or nonvolatile, the latter usually predominating. Fixed oils often contain in combination small quantities of some of the soluble volatile acids, such as butyric, valerianic, caproic, and caprylic, which decrease in solubility as well as in volatility in the order mentioned. The Reichert-Meissl number is a measure of the amount of volatile acids present in a fixed oil and is indicated by the number of cubic centimeters of decinormal alkali required to neutralize the volatile fatty acids obtained from 5 grams of fixed oil.

The determination of volatile acids was carried out in accordance with the method recommended by the Association of Official Agricultural Chemists² and consisted essentially in saponifying a weighed portion of the oil in 95 per cent alcohol by means of sodium-hydroxid solution, then evaporating the alcohol, dissolving the soap in water,

¹ United States Pharmacopoeia, 8th revision, p. 527.

² Official and provisional methods of analysis. Bulletin 107 (revised), Bureau of Chemistry, U. S. Dept. of Agriculture, 1910, p. 139.

acidifying, and distilling with steam. By titrating the distillate with standard alkali solution the volatile-acid equivalent of 5 grams of fixed oil, expressed in cubic centimeters of tenth-normal alkali solution, was readily ascertained. By this method the Reichert-Meissl number, or the amount of volatile acids in the oil, was found to be 0.64, which indicates that a very small percentage of the lower volatile acids is present.

SOLUBLE ACIDS.

The percentage of soluble acids was also determined according to the method prescribed by the Association of Official Agricultural Chemists¹ and consisted in liberating the fatty acids from a saponified weighed portion of oil by the addition of a definite amount of half-normal hydrochloric acid. After washing the liberated fatty acids several times with hot water, the aqueous solution was titrated with tenth-normal alkali. By means of the factor 0.0088 the weight of the soluble acids in the saponified oil was calculated as butyric acid. By this method it was found that 6.697 grams of raisin-seed oil contained 0.0264 gram of butyric acid, which corresponds to 0.394 per cent of soluble acids.

INSOLUBLE ACIDS.

The amount of insoluble fatty acids (Hehner value) was also determined by the method adopted by the Association of Official Agricultural Chemists.² The insoluble fatty acids remaining from the determination of the soluble acids were drained and dried. They were then transferred to a weighed dish and the filter paper through which the soluble acids had been filtered was washed with absolute alcohol and the flask which contained the insoluble acids was rinsed with absolute alcohol. The filtrate and washings were then added to the insoluble acids in the weighed dish. After drying in a desiccator, when the alcohol had evaporated and the weight of the acids had become constant, the weight of the insoluble fatty acids in the oil corresponded to a total of 94.4 per cent. Since the uses of an oil are largely dependent upon the nature of the insoluble acids which it contains in the form of glycerids and since so large a proportion of raisin-seed oil consists of insoluble acids, this subject will be discussed in detail later in this bulletin.

ACETYL VALUE.

As a measure of the hydroxylated glycerids in a fixed oil, the determination of the acetyl value is usually made. Acetic-acid anhydrid is employed to react with the hydroxy groups that may be contained in the fatty acids, the acetyl radical (C_2H_3O) replacing the hydrogen of the hydroxy (OH) group. The method used was again that

¹ Op. cit., p. 138.

² Op. cit., p. 139.

recommended by the Association of Official Agricultural Chemists.¹ After acetylation of the oil with acetic-acid anhydrid it was washed free from excess acid and dried. By saponifying a weighed portion of the acetylated oil, dissolving the soap in water, and decomposing the soap with a quantity of sulphuric acid equivalent to the amount of potash added, the free acids were liberated. The insoluble fatty acids separated in the form of a layer, while the soluble acid (acetic) which was taken up during acetylation remained in solution. After carefully washing the oily acids with boiling water, the aqueous acid solution was titrated with standard alkali and the amount of acetic acid determined.

The acetyl value of raisin-seed oil, after correcting for the soluble volatile acids as suggested by Lewkowitsch,² was found to be 16, which indicates that 16 milligrams of potassium hydroxid were required to neutralize the acetic acid obtained by the saponification of 1 gram of acetylated oil. This value is considerably lower than the results obtained for grape-seed oil recorded by Marre,³ which varied from 20.8 to 25.0.

UNSAPONIFIABLE MATTER.

Besides the glycerids of fatty acids, most fixed oils contain small quantities of unsaponifiable matter, which consists principally of an alcoholic substance, phytosterol, together with some coloring matter and compounds of a waxlike character. The amount of unsaponifiable matter sometimes varies in the different oils, depending upon the condition of the material as well as the methods of extraction. Although these constituents are of little practical value, a determination was made by saponifying a quantity of the oil with alcoholic potassium hydroxid and subsequently shaking out the aqueous solution of the soap with ether, and the oil was found to contain 0.78 per cent. The determination is useful chiefly for the detection of adulterations of vegetable oils with waxes, paraffin, or mineral oils.

DETAILED EXAMINATION OF THE INSOLUBLE ACIDS.

The insoluble acids, which comprise such a large proportion (94.4 per cent) of the constituents of raisin-seed oil, determine in a general way the usefulness of this oil. Insoluble acids are variable in character, some being solid at ordinary temperatures and others liquid. Oils with solid acids predominating are usually found useful in the manufacture of soaps, as, for instance, coconut and palm oils, which contain large quantities of such solid acids as stearic, palmitic, and myristic.

¹ Op. cit., p. 142.

² Lewkowitsch, J. *Chemical Technology and Analysis of Oils, Fats, and Waxes*, vol. 1, 1909, p. 342.

³ Marre, F. *L'huile des pépins de raisin. Revue Générale de Chimie Pure et Appliquée*, vol. 14, 1911, p. 186.

The nature of the liquid acids of an oil also determines in many cases its practical application. Certain liquid acids are useful in soap making, while others possess drying properties, depending largely upon their constitution. It must be understood, however, that the free acids are not found to any great extent in a fixed oil, but are present as glycerids.

The insoluble acids of raisin-seed oil are both solid and liquid. Since the liquid acids are greatly in excess, the mixed acids when liberated from the oil are liquid.

MIXED ACIDS.

The insoluble acids separated from the oil after saponification by the addition of hydrochloric acid were obtained in the form of a golden-yellow liquid with practically no odor and with a bland, fatty taste becoming slightly bitter. The specific gravity at 24° C. was 0.8948, and the index of refraction at the same temperature was 1.4622. The acids began to congeal at 12.5° C. and were entirely solid at 11.5° C.

By titrating the oil with standard potassium hydroxid the neutralization value of the mixed acids was found to be 174.5. The iodine value, determined in the manner previously mentioned, was 137.

SEPARATION OF THE SOLID AND LIQUID ACIDS.

In order to separate the solid and liquid acids in the mixture, the lead-ether method was used. The effectiveness of this method depends upon the insolubility of the lead salts of the solid fatty acids in cold ether, the lead salts of the liquid acids being soluble. The method used for the preparation of the lead salts of fatty acids was that recommended by the Association of Official Agricultural Chemists under the test for peanut oil.¹ After saponifying about 5 grams of the oil with alcoholic potash, the soap mixture was neutralized with dilute acetic acid. The neutralized mixture was washed into a flask containing 25 cubic centimeters of water and 30 cubic centimeters of a 20 per cent solution of lead acetate. After boiling, the precipitated soap was cooled by immersing the flask in water and was agitated to cause the lead soap to stick to the sides of the flask. After decanting the water and excess of lead acetate and washing the adhering soap with water and 90 per cent alcohol, 50 cubic centimeters of ether were added and the mixture allowed to stand, after which it was heated for five minutes on a water bath with reflux condenser. The ether solution of the soap was then cooled in a refrigerator over night and the insoluble soap allowed to crystallize out.

¹ Official and provisional methods of analysis. Bulletin 107 (revised), Bureau of Chemistry, U. S. Dept. of Agriculture, 1910, p. 145.

To secure a separation of the solid fatty acids from the liquid acids, the method prescribed by the Association of Official Agricultural Chemists was again followed.¹ After filtering the lead-salt mixture, the insoluble lead soap on the filter was washed into a flask, decomposed with hydrochloric acid, and the mixture heated until the fatty acids melted. The flask was filled with hot water to bring the melted acids into the neck, and then cooled. After decanting the water, the acids were again washed in a similar manner. The solid acids were finally dissolved in hot absolute alcohol and the solution allowed to evaporate. After drying and weighing, the amount of solid acids in the raisin-seed oil was found to be 8.4 per cent.

The ether filtrate from the lead soap, which had been saved and which contained the lead salts of the liquid fatty acids of the oil, was placed in a separatory funnel and decomposed with 40 cubic centimeters of a 20 per cent solution of hydrochloric acid. The precipitated lead chlorid was separated from the ether solution and the latter washed until free from acid. The ether solution of the liquid fatty acids was evaporated in an atmosphere of carbon dioxide to prevent the oxidation of the acids. After evaporation of the ether, the amount of liquid fatty acids was found to be 84.7 per cent.

SOLID ACIDS.

The solid acids obtained by the above process appeared as a white, tallowlike, odorless, tasteless mass. The mixed solid acids after recrystallization melted at 57° to 58.5° C. By titrating a weighed portion of the solid acids with standard alcoholic potassium-hydroxid solution, 1 gram required 0.2163 gram of potassium hydroxid, which corresponds to a neutralization value of 216.3. Calculated from this neutralization value, the mean molecular weight of the solid acids is 259.

The neutralization value and the mean molecular weight of the mixed solid acids would seem to indicate the presence of palmitic and stearic acids, inasmuch as palmitic acid has theoretically a neutralization value of 219.1 and a molecular weight of 256, while stearic acid has a neutralization value of 187.5 and a molecular weight of 284. By comparing the theoretical figures with those actually obtained, it appears that palmitic acid is considerably in excess of stearic acid. This is further partially substantiated by the fact that the melting point of the mixed acids is much lower than that of pure stearic acid, which melts at 69° C., and is even lower than that of pure palmitic acid, which melts at 62° C. As the mixed acids were recrystallized only once, the presence of traces of impurities would perhaps account

¹ Op. cit., p. 142.

for the rather low melting point. Commercial stearic acid, which contains some impurities, is known to melt as low as 56° C.

Taking advantage of the difference in solubility of these two acids in alcohol and hydroalcoholic solutions, a precipitation method was applied with good success. A small quantity of the mixed solid acids was dissolved in alcohol to a clear solution. The alcoholic solution was diluted with a small quantity of water, which produced a flocculent precipitate. This fraction was separated and dried. Another equal quantity of water was added to the filtrate, which produced a second precipitate, and this was likewise separated and dried. The neutralization value of fraction 1 was determined in the usual manner and was found to be 197.1, while that of fraction 2 was 220.3. These values correspond very closely to stearic and palmitic acids, respectively.

In order to ascertain the approximate proportion of the two acids in the mixture, a calculation was made from the mean molecular weight of the mixed acids, according to the method suggested by Lewkowitsch,¹ which is as follows:

Let X = percentage of palmitic acid, and M_1 = molecular weight.

Y = percentage of stearic acid, and M_2 = molecular weight.

M = mean molecular weight obtained.

$$X + Y = 100.$$

$$\frac{M_1 X}{100} + \frac{M_2 Y}{100} = M.$$

Substituting the values of M_1 , M_2 , and M in the formula, the following equation is obtained:

$$\frac{256 X}{100} + \frac{284 Y}{100} = 259$$

Calculating the values of X and Y , the percentage of palmitic acid was found to be 89.3 and of stearic acid 10.7. A mixture of palmitic and stearic acids in the proportion of 90 to 10 actually gives a neutralization value of 216.77 and a mean molecular weight of 258.8; hence, the percentages found indicate very closely the proportion of these two acids in the mixed solid acids.

Since 8.4 per cent of the original oil consists of solid acids, there is therefore 7.5 per cent of palmitic acid and 0.9 per cent of stearic acid in the oil. Since the oil consists of the glycerids of the fatty acids, it was necessary to reduce these percentages to terms of the corresponding glycerids. The glycerid palmitin contains 95.29 per cent of palmitic acid, and the glycerid stearin contains 95.73 per cent of stearic acid; therefore, making the calculations from the percentages of the free acids, it is found that raisin-seed oil contains 7.87 per cent of palmitin and 0.94 per cent of stearin.

¹ Lewkowitsch, J. Chemical Technology and Analysis of Oils, Fats, and Waxes, vol. 1, 1909, p. 515.

LIQUID ACIDS.

The liquid acids of all fixed oils are usually unsaturated compounds with one or more double bonds in their molecular structure. Such unsaturated compounds possess the property of taking up oxygen, or, in other words, are readily oxidized, the compounds being changed into saturated hydroxylated compounds. In the case of the unsaturated fatty acids the resulting oxidation products are hydroxylated acids, which are easily characterized and identified.

When an oil consists largely of liquid fatty acids, as is the case with raisin-seed oil, the composition of these liquid acids or their glycerids is essentially important, since it largely determines the value of the oil in its application to the arts and manufactures. For use in the manufacture of paint, the presence of certain fatty acids is required; for soap-making purposes certain other acids are necessary; and for use as an edible oil still others must be present. The liquid acids obtained from raisin-seed oil were of a golden-yellow color and bland, lardlike odor. The taste was fatty and bland, with a bitter aftertaste. The specific gravity at 25° C. was 0.9020 and the refraction at 25° C. was 1.4640. The neutralization value of the liquid acids was 199.8 and the iodine absorption value 146.1.

Identification of the liquid acids.—In order to learn the composition of the mixed liquid acids obtained from raisin-seed oil, a small quantity of the acids was oxidized according to the method of Hazura and Grüssner¹ by means of a 1½ per cent solution of potassium permanganate. Of the fatty acids 5 grams were neutralized with 6 cubic centimeters of a 30 per cent solution of caustic potash. The resulting soap, after being dissolved in about 300 cubic centimeters of water, was oxidized with an equal volume of the potassiumpermanganate solution, added gradually and with constant agitation. Sufficient sulphurous acid was finally added to dissolve the manganese compounds and to impart an acid reaction. The precipitated hydroxylated acids were then extracted with ether in successive portions to remove the ether-soluble dihydroxystearic acid, if present. The ether solution was evaporated and the crystals recrystallized from alcohol. The crystals melted between 134° and 137° C. and were therefore dihydroxystearic acid, which when pure melts at 131.5° to 136.5° C. and is obtained by the oxidation of oleic acid.

The acids which were insoluble in ether were boiled successively with water, several deposits of crystals being obtained. The crystals melted at 158° to 159° C., which corresponds to the melting point of an isomer of sativic acid (tetrahydroxystearic acid) obtained as an

¹ Hazura, K., and Grüssner, A. Zur Kenntnis des Olivenöls. Monatshefte für Chemie, Bd. 9, 1888, p. 944.

oxidation product of linoleic acid. In addition to dihydroxystearic acid and tetrahydroxystearic acid a few crystals were obtained which melted at 207° C. and which were probably hexahydroxystearic acid or linusic acid, which when pure melts at 203° to 205° C. The presence of this oxidation product would seem to indicate that a trace of linolenic acid also exists in the liquid acids.

The liquid acids of raisin-seed oil apparently consist for the most part of oleic and linoleic acids, with a possible trace of linolenic acid. The neutralization value of 199.8 and the iodine absorption 146.1 of the liquid acids both point to the presence of oleic and linoleic acids, since the neutralization value of pure oleic acid is 198.9 and the iodine absorption 90.07, while linoleic acid possesses a neutralization value of 200.4 and an iodine absorption value of 181.4.

The mean molecular weight of the liquid acids, calculated from the neutralization value 199.8, was found to be 280.78, which further supports the view that the acids consist mainly of oleic and linoleic acids, which have a molecular weight of 282 and 280, respectively. Using the equation given under solid acids and calculating from the mean molecular weight (280.78) for the determination of the proportions of oleic and linoleic acids present in the mixed liquid acids, it was found that linoleic acid predominates, being present to the extent of 61 per cent, while the remaining 39 per cent corresponds to oleic acid.

These results were further confirmed by calculating the proportions of oleic and linoleic acids from the iodine value of the mixed acids, which was 146.1. The iodine value of oleic acid is 90.07 and of linoleic acid 181.42. Hence, letting X equal the percentage of oleic acid and Y the percentage of linoleic, the following equations are derived:

$$\begin{aligned} X + Y &= 100. \\ \frac{90.07 X}{100} + \frac{181.42 Y}{100} &= I \text{ (iodine absorption of mixed acids).} \end{aligned}$$

Substituting the value of I and finding the values of X and Y, the results indicate that 61.3 per cent is linoleic acid and 38.7 per cent is oleic acid.

It has been previously stated that 84.7 per cent of the original oil consists of liquid fatty acids. Assuming that the proportion of linoleic and oleic acids in the liquid acids is approximately 61 and 39 per cent, the original oil contains about 51.7 per cent of linoleic and 33 per cent of oleic acid.

From these percentages the amounts of the glycerids linolein and olein can be calculated. It is known that linolein contains 95.67 per cent of linoleic acid and olein contains 95.7 per cent of oleic acid. Hence, calculating by simple proportion, it is found that the oil consists approximately of 54 per cent of linolein and 34.48 per cent of olein.

Briefly summarizing the results obtained from the chemical examination of raisin-seed oil, the following composition is indicated:

	Per cent.
Linolein.....	54
Olein.....	34.48
Palmitin.....	7.87
Stearin.....	.94
Free acids (calculated as oleic acid).....	.62

The remainder of the oil consists of small amounts of volatile acids, soluble acids, and unsaponifiable matter, with possibly a trace of the glycerid of linolenic acid.

DRYING PROPERTY OF RAISIN-SEED OIL.

Since the fixed oil of raisin seeds contains constituents with drying properties, it was thought advisable to determine the actual drying value in order to compare it with some of the standard drying oils. The drying property of a fixed oil depends upon its power to absorb oxygen and it must necessarily contain constituents which are readily oxidizable. This property is also greatly influenced by the condition of the oil. In the raw condition, untreated in any way, oils usually possess the power of oxygen absorption to a much less degree and with much less rapidity than when subjected to certain treatments, such as boiling or heating with compounds rich in oxygen. Simple continued heating of an oil modifies this property of oxygen absorption, rendering the oil more powerful in this respect. The most common method, perhaps, of rendering oils more susceptible to the absorption of oxygen is treatment with the so-called "driers." Common among these are lead oxid (litharge), manganese dioxid, and a combination of manganese with rosin known as manganese rosinate.

In order to determine the drying property of raisin-seed oil, the crude raw oil was treated first by heating for 30 minutes at 200° to 210° C.; second, by heating for 15 minutes at 190° to 200° C. with lead oxid varying in quantity from one-half of 1 to 4 per cent; and, third, by heating for 15 minutes at 190° to 200° C. with manganese dioxid varying in quantity from 1 to 4 per cent. A sample of raw linseed oil, chosen for the purpose of comparison, was treated in the same manner.

As has been stated, the drying of oils is accompanied by the absorption of oxygen. These results, therefore, an increase in weight and the percentage of this increase determines the drying quality of the oil. Although some oils when exposed to the air gradually absorb oxygen and become dry, yet the less the quantity the more rapid the process, and in order to complete the experiments as rapidly as possible they were carried out in the following manner: Thin layers of the prepared oils, ranging in weight from 12 to 14 centigrams, were

spread evenly over small glass plates having an area of 25 square centimeters. The plates were then set aside in a place free from dust but with free access of air. They were carefully weighed from time to time and the percentage of increase computed. The weighings were conducted over a period covering the time required in each case for the maximum absorption, the period varying with the different samples and the different treatments. The results are given in Table I.

TABLE I.—*Oxygen absorption, or percentage of increase in weight, of films of raisin-seed and linseed oils when treated in various ways.*

Length of exposure. Hours	Raw.		Heated.		Heated with PbO.								Heated with MnO ₂ .					
					One-half of 1 per cent.		1 per cent.		2 per cent.		4 per cent.		1 per cent.		2 per cent.		4 per cent.	
	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.	Raisin-seed oil.	Linseed oil.
P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5					1.7	2.29							(1)	(1)	0.3	0.29	0.07	0.27
6			0.24	0.23			5.1	7.8	5.7	9.3	2.8	9.8						
22					6.76	11.6	8.4	13.3	8.4	12.8	7.6	12.0						
23																		
24	(1)	(1)	.32	.47									(1)	(1)	.3	.43	.13	.73
29							8.8	13.7	8.78	13.0	8.2	12.0	(1)	(1)	.3	1.3	.47	9.9
48	(1)	(1)	.4	.47	8.67	13.2	8.8	13.7	8.2	13.2	7.3	12.2	(1)	(1)	.37	8.1	.54	13.7
72	(1)	(1)	.4	.47	9.12	13.2	8.8	13.5	8.1	13.0	7.3	11.9	0.23	0.94	.52	13.7	1.5	13.9
96			1.2	1.1	8.6	13.2	8.2	13.3	7.2	12.8	6.4	11.7	.63	3.6	.82	13.9	2.4	13.7
120	(1)	(1)	2.0	1.66	8.0	12.7	7.7		7.2	12.8	6.2	11.7	1.1	10.7	1.7	13.9	3.8	13.5
144	(1)	(1)																
168	(1)	(1)	5.87	8.4	6.4	12.6	7.1		6.66	12.6	6.0	11.7	4.64	14.0	5.0	12.9	8.29	13.0
192	0.24	0.76	8.52	13.1									6.7	13.5	7.28	12.3	9.99	12.7
216	.4	3.3	10.6	14.1			6.1		5.9	11.6	5.4	11.4	8.5	13.3	8.83	11.2	9.92	12.1
240	.65	7.8	9.7	13.4									9.36		9.58		9.79	
264			9.1	12.9									10.0		10.0		9.38	
288	1.95	14.1	8.76	12.6									9.9		9.73		8.85	
312	2.75	13.1																
336	4.53	12.4											8.88		8.84		8.1	
360	6.88	11.1	7.0	11.7														
384	8.43	10.6																
408	9.32	10.6																
432																		
456																		
480	7.1	9.6																

1 No increase.

An analysis of the table shows that the raw oils absorbed oxygen very slowly, both oils beginning absorption at about the same time. The percentage of increase, however, was much more rapid from hour to hour in linseed oil than in the oil from raisin seeds. The latter attained its maximum absorption in 408 hours, a total of 9.32 per cent of oxygen being absorbed, while the linseed oil reached its limit in 288 hours, with a total oxygen absorption of 14.1 per cent. Both films were dry but gelatinous, the raisin-seed oil film being a trifle more sticky than that of the linseed oil.

The heated oils absorbed oxygen much more quickly than the raw oils. An increase in the weight was noted at the first weighing in 6

hours. The increase was steady and considerably more rapid than in the raw oils, the maximum in both oils being reached in 216 hours. The percentage of absorption was practically the same as in the raw oils, but the time of absorption was less in the raisin-seed oil, the heating, therefore, having the effect of hastening the drying.

The experiments show also that by heating the oils with lead oxid in quantities varying from one-half of 1 to 4 per cent, oxygen was absorbed with much greater rapidity than by the heated or raw oils. When heated with 1 and 2 per cent of lead oxid the films had practically become set in 6 hours, the absorption in raisin-seed oil amounting to 5.1 and 5.7 per cent, respectively, and in linseed oil to 7.8 and 9.3 per cent, respectively. Each of the oils treated with the varying quantities of lead oxid produced a film which at the end of 23 hours was dry, with only a slight stickiness. The maximum absorption in the case of raisin-seed oil was 8.1 to 9.12 per cent, and in linseed oil 12.2 to 13.7 per cent, which was about the same range. When heated with 4 per cent of lead oxid there was less total absorption in both oils than when heated with one-half of 1, 1, and 2 per cent. Apparently the oils heated with 1 and 2 per cent dried most rapidly in each case.

Manganese dioxid seemed to be much less efficient as a drier than the lead oxid, the length of time necessary to dry the films being in all cases considerably longer than when the oils were heated with lead oxid. Four per cent of manganese dioxid appeared to be the most favorable, the films of both oils drying more rapidly than when containing a less quantity. The maximum oxygen absorption of raisin-seed oil (9.99 per cent) was not reached until 192 hours, while linseed oil required only 72 hours, the total absorption being 13.9 per cent. Both the raisin-seed and linseed oils when heated with manganese dioxid produced films of about the same texture, drying to about the same degree of hardness as with the lead oxid.

In texture and tenacity the films in all the experiments bore a close resemblance, those of linseed oil being a trifle harder and a little less sticky than those of the raisin-seed oil. All were transparent and somewhat elastic and insoluble in ether. In all the experiments there seemed also to be a continual decrease in weight after the maximum absorption had been reached, the films becoming harder and less sticky.

COMPARISON OF RAISIN-SEED OIL WITH OTHER DRYING OILS.

Since only unsaturated fatty acids possess the property of taking up oxygen, this class of constituents is necessary to drying oils. Stearic acid is a saturated fatty acid and does not change on exposure to air. Oleic acid, on the other hand, contains two atoms of hydrogen less than stearic acid and is a common unsaturated fatty acid present

in many fixed oils. This acid, therefore, readily takes up oxygen. Saturated and unsaturated fatty acids are usually present in oils in combination with glycerin and are known as glycerids. These glycerids in the cases of some of the more common fats are known as olein, palmitin, and stearin.

Most drying oils contain constituents in common upon which the drying property depends. The most important of these constituents are the glycerids of linolenic and linoleic acids. These compounds absorb oxygen from the air very readily, forming a neutral compound known as linoxyn, which is the characteristic end product of all drying oils used in paints and varnishes. This property of oxygen absorption is sometimes called autoxidation. When exposed to the air, drying oils will oxidize, the time required for complete oxidation, or formation of linoxyn, depending upon the nature of the oil and the thickness of the layer exposed. This oxidizing property is favorably influenced when certain substances known as siccatives or driers are digested with the oil. Metallic oxids, such as lead oxid and manganese dioxid, and such salts as manganese and lead-resinates are commonly employed siccatives. When oils are digested with any of these compounds the change of the unsaturated acids to linoxyn is considerably hastened, the siccatives, in a catalytic way, bringing about more rapid absorption. This is clearly shown in Table I.

Among the drying oils the most important are linseed, walnut, China-wood (tung), hempseed, sunflower, and poppy-seed oils. Those most commonly used in this country are linseed and China-wood oils. Linseed oil is the only one produced in the United States and occupies a foremost position as a paint oil. The liquid constituents of the drying oils mentioned contain either linolenic or linoleic acids, or isomerids of these acids, the acids occurring in combination with glycerin as glycerids. Oleic acid in the form of its glycerid, olein, is also a constant constituent of these oils. The linoleic and linolenic acids, however, are of chief concern from the standpoint of the usefulness of the oils in the manufacture of paints and varnishes.

The experiments recorded in Table I show that the maximum absorption of raisin-seed oil was 10.6 per cent, while that of linseed oil was 14.1 per cent. In both cases the figures were obtained from experiments conducted with the heated oils. When siccatives were employed the maximum absorption was not increased, but the operation was greatly hastened. This has also been shown by Lippert,¹ who experimented with lead oxid (litharge) and manganese resinate as driers. Linseed oil was heated to 150° C. for 15 minutes with

¹ Lippert, Walther. Zur Ermittlung der von trocknenden Oelen und Firnissen absorbirten Sauerstoffmenge. Zeitschrift für Angewandte Chemie, 1898, Heft 19, p. 431.

varying percentages of driers, the weight of the film being from 0.11 to 0.13 gram per 100 square centimeters. The following results were recorded:

TABLE II.—*Oxygen absorption of linseed oil when heated with manganese resinate and lead oxid.*

Heated with—	Gain in weight after—				Remarks.
	12 hours.	23 hours.	36 hours.	39 hours.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Manganese resinate:					
0.02 per cent.	2.1		15.97		17 per cent in 55 hours.
0.06 per cent.	4.89		15.48		15.69 per cent in 40 hours.
0.15 per cent.	6.6		14.45		
0.2 per cent.	6.46		14.02		
Lead oxid:					
0.34 per cent.		8.5		11.1	
1.1 per cent.		13.5		13.9	
2.5 per cent.		12.7			
6.8 per cent.		12.3			

The experiments with raisin-seed oil heated with lead oxid seem to bear out Lippert's conclusion that the use of driers beyond a certain percentage produces no appreciable difference in the absorptive power. In both raisin-seed and linseed oils (Table II) the use of more than 1 per cent of lead oxid indicated no increase in the absorptive power, the films being practically dry in 23 hours with almost the maximum of oxygen absorption. The use of more than 1 per cent of manganese dioxid also seems to have no distinctly favorable influence upon the drying of the films of either raisin-seed or linseed oil.

A number of fixed oils have been investigated by Weger¹ and Kuhl² with respect to their oxygen-absorption properties and for the sake of comparison with raisin-seed oil are here given:

TABLE III.—*Oxygen-absorption power of certain drying oils.*

Kind of oil.	According to Weger.		According to Kuhl.
	<i>Per cent.</i>	<i>Days.</i>	<i>Per cent.</i>
Linseed (foreign).....	18	3-7	17.5
China wood.....	14-16	3-8	
Hempseed.....	13.5	4-4½	16.8
Poppy seed.....	13.4	6½	15.6
Sunflower.....			14.8
Walnut.....			19.6
Rapeseed.....	7.6	7	
Olive.....	5.2	20	
Peach kernel.....	10.5	29	

These results show that the foreign linseed oil possesses a greater power of oxygen absorption than the American linseed oil, which was

¹ Weger, Max. Ueber die Sauerstoffaufnahme der Oele und Harze. Chemische Revue über die Fett- und Harz-Industrie, Jahrg. 5, 1898, p. 249.

² Kuhl, Dr. Die Firnisbildung der Oele. Pharmazeutische Zentrallhalle, Jahrg. 51, 1910, p. 185.

used in the experiments previously discussed. It will be seen by carefully comparing raisin-seed oil with the oils mentioned that although it possesses drying properties somewhat lower than such standard oils as linseed, China wood. and walnut, yet it has good drying properties as compared with the other drying and semidrying oils.

RAISIN-SEED OIL AS A PAINT AND VARNISH OIL.

Taking into consideration the ready-drying property of raisin-seed oil, especially when treated with an ordinary drier such as lead oxid, it should be of value in the paint and varnish industries. Not only does the oil when treated with driers absorb oxygen rapidly, but it compares favorably with linseed oil in this respect. Granting, however, that linseed oil absorbs oxygen more rapidly, the nature of the films after drying is much the same, both being transparent and elastic. The linseed-oil film differs apparently only in being slightly less tacky.

In order to ascertain its value as a paint oil, a small quantity of the oil was submitted to a paint manufacturer for a practical test. Two kinds of paint were made up, one being an oxid red and the other a graphite. The oxid-red paint was made the same as with linseed oil. The vehicle of the paint was composed of 8 parts of raisin-seed oil, 1 part of spirits of turpentine, and 1 part of linseed oil and gum japan. The driers used in the japan were litharge and oxid of manganese. The base of the paint was red oxid.

The paint was found to be of the same usual body as linseed-oil paint and flowed nearly as well under the brush. It dried somewhat more slowly but produced a high-gloss finish. Red oxid was chosen because this particular oxid is known to be very destructive to linseed oil, the color quickly losing its brilliancy and the paint becoming dead and bluish purple.

After four months' exposure, from August to December, the paint prepared with raisin-seed oil had a fine film with a good finish and the oxid was still as brilliant as when applied, which was exactly contrary to the results obtained with the linseed-oil paint. In August a sample of the paint was applied to corrugated iron on the south side of a building exposed to the strongest sunlight in a smoky district adjacent to blast furnaces which continually gave off gases. In March, after seven months' exposure to these conditions, the paint still retained the true, perfect color of the oxid and the finish was intact. In the opinion of the manufacturers, this particular paint "stood up" very well, far better in fact than linseed-oil paint under the same conditions.

Raisin-seed oil is decidedly resistant to heat and declines to take on color even when heated to 500° F., whereas linseed oil darkens

considerably and takes on a greenish color. The somewhat slower drying properties of raisin-seed oil should not be especially detrimental to its usefulness, since this can doubtless be overcome by treatment of the raw oil with proper driers. The preliminary experiments have shown that it can be used in the manufacture of paint, and in the particular instance mentioned it acted better than linseed oil.

Since raisin-seed oil acts so well in the manufacture of paint it could unquestionably be used also with equal success in the manufacture of varnish, in which at present linseed and China-wood oils are used almost entirely.

As raisin-seed oil contains a large quantity of linoleic acid, together with some linolenic acid, it should also be capable of being oxidized to produce what are commonly known as oxidized or blown oils. These are drying or semidrying oils which have been artificially oxidized by heating in a current of air or oxygen and find extensive use in the various industries. It is probable that by the oxidation of raisin-seed oil there would result a substance similar to that formed from linseed oil (linoleum mass) which is used so extensively as a basis for making linoleums.

RAISIN-SEED OIL AS A SOAP-MAKING OIL.

For the purpose of testing the usefulness of raisin-seed oil in the manufacture of soap, a small quantity was saponified by the "cold process" with a calculated amount of strong sodium-hydroxid solution (about 30 per cent), the alkali being slightly in excess of the amount required to exactly saponify the given weight of oil. After standing 24 hours the excess of water was separated from the mass and the soap pressed into a cake and allowed to dry. A hard, compact soap resulted, which after several months still retained its white appearance, with only a trace of discoloration. Although this small quantity was made in a very crude way, yet, to all outward appearance at least, the sample, which produced a copious lather, showed that raisin-seed oil has some of the qualities of a soap oil.

This favorable preliminary test caused a desire to obtain the judgment of practical soap makers regarding the merits of the oil as a soap material. Accordingly, a sample of the fixed oil was submitted to a prominent soap manufacturer for a practical test. The soap chemist described the oil as being fair in color, but causing a somewhat deeper coloration upon saponification than some of the first-class soap oils. It was stated, however, that this could easily be removed by repeatedly salting out. It was also suggested that a process of refining or bleaching would remove the objectionable color and make it very suitable for use in the soap industry.

The soap was described as being about equal to olive-oil soap in color and as having a pleasant aromatic odor. Since the oil contains only a small percentage of palmitin and stearin, it was suggested that it could be used advantageously in the manufacture of toilet soaps in connection with tallow, palm oil, or coconut oil, which would have a tendency to produce a firmer soap with a higher melting point.

The fixed oils best adapted to the manufacture of fancy soaps are olive oil, palm oil, coconut oil, and almond oil. The latter, owing to its scarcity, is not used except for special purposes. Oils with high saponification value, such as coconut and palm oils, are used in connection with animal fats in order to increase their solubility and the lathering properties of the soap. Olive oil, which is much used in the manufacture of the finer grades of soaps, has a saponification value only slightly higher than raisin-seed oil.

It appears, therefore, from the tests conducted, that the oil of raisin seeds possesses qualities which should make it of considerable value in the soap industry.

AVAILABLE QUANTITY AND VALUE.

After removing the sugary matter for the preparation of the sirup there was found to be a reduction of about 20 per cent in the total weight of the seeds. Therefore, the weight of the seeds remaining would be from 2,400 to 3,200 tons. The average yield of oil being about 14.5 per cent, the total quantity of oil capable of being manufactured from this material would be approximately from 348 to 464 tons. Calculating from the specific gravity of the oil, this represents from 90,390 to 120,520 gallons available annually.

As a paint oil the value of the yearly production should approximate \$35,000 to \$50,000. In the manufacture of soap its value would perhaps be somewhat less.

TANNIN.

EXTRACTION.

In order to separate the tannin from the seeds after the extraction of the fixed oil, 1 kilogram of the residue was boiled out repeatedly with water and the aqueous extract evaporated. After evaporation there resulted 292 grams, or 2.92 per cent, of a semisolid extract, with a deep reddish brown color and a strong astringent taste. The moist extract contained 43.5 per cent of water; therefore, there would be 16.5 per cent of dry extract available. The dry extract was deep brownish red in color, breaking with a glassy fracture and having the odor of licorice.

ANALYSIS.

Upon analysis the dry extract was found to contain 28.38 per cent of tannins. Nontannins were present to the extent of 60.82 per cent.

The total amount of soluble solids was 89.2 per cent and of the insoluble material 10.8 per cent.

According to Trimble, tannins are divided into two general classes, known as the gallotannic-acid group and the oak-tannin group, the former including such tannins as are found in nutgall, chestnut bark, pomegranate bark, and sumac, while the latter group includes oak, mangrove, kino, canaigre, etc. The two groups are characterized by their behavior toward certain reagents, such as lime water, bromin water, and ferric chlorid. In order to determine the class to which raisin-seed tannin belongs, tests were made with these reagents. With lime water a reddish precipitate resulted, with bromin water a yellowish turbidity, and with ferric chlorid a green coloration was produced. These tests would place the extract in the oak-tannin group, since the same reactions are produced with oak tannins, while the gallotannic-acid group produces a blue precipitate with lime water, no reaction with bromin water, and a blue precipitate with ferric chlorid.

DYESTUFF.

In extracting the tannin considerable reddish coloring matter was also extracted. Although this coloring matter may be of no great importance as a dyestuff, its presence may add to the usefulness of the extract, since tanners often desire a coloring matter in connection with tanning extracts. Therefore, an examination was made as to its coloring properties.

As part of the coloring matter still remained in the residue after the extraction of the tannin, a small quantity of this residue was heated on a water bath with a 1 per cent solution of sodium hydroxid in successive portions. The deep purple-red solution was decanted and filtered in each case and neutralized with sulphuric acid. The dyestuff was precipitated in the form of a reddish brown flocculent mass, which was filtered, dried, and ground to a powder. In this manner about 18 per cent of a brownish red dyestuff was obtained, which was found to be readily soluble in dilute aqueous alkali to a purple-red color. In dilute acids it was less soluble, a yellowish coloration resulting. The powder was soluble in hot water to a brownish red solution. It was almost insoluble in ether, chloroform, and benzene, but was readily soluble in methyl alcohol to a red solution. It was somewhat less soluble in ethyl alcohol to a light brownish solution.

To test its properties as an indicator a small amount of the dye was dissolved by means of a few drops of tenth-normal sodium hydroxid and the purple-red solution diluted with water until the color was still distinguishable. Upon the addition of standard acid solution drop by drop, a sharp end reaction was noted, the change from purple red to yellow being readily seen. An aqueous solution,

when treated with mordant reagents, reacted by giving precipitates as follows:

Potassium bichromate.....	Brownish red.
Ferrous sulphate.....	Brownish red.
Stannous chlorid.....	Bright red.
Copper sulphate.....	Dirty brown.
Alum.....	Pale brownish red.
Zinc sulphate.....	Dark red.

After precipitating the dye from its alkaline solution by neutralizing with acid, the filtrate still possessed a reddish color, and after being evaporated down to about one-half its volume it was deep brown red in color. A small strip of cotton cloth was introduced into this solution and heat applied for about two hours, after which the cloth had taken on a deep-brown color. The dyed cloth was then mordanted with alum, after which it was dried and thoroughly washed with soap and water. After washing several times the cloth had a brownish red color, practically identical with that of the dyestuff.

Usually a variety of shades can be produced with a dye by means of different mordants. In order to ascertain the range of shades possible with the different metallic mordants, a crude dyeing experiment was carried out. The mordants chosen were chromium, iron, tin, copper, aluminum, and zinc. After immersing narrow strips of cotton cloth in the mordant solution for several hours they were transferred to neutral solutions of the coloring matter in question and heated for several hours, after which the strips were again immersed in the mordant and finally washed. The following shades were produced with the various mordants:

Potassium bichromate.....	Pale brownish violet.
Iron sulphate (ferrous sulphate).....	Grayish violet.
Tin chlorid (stannous chlorid).....	Light red.
Copper sulphate.....	Reddish violet.
Alum (aluminum-potassium sulphate).....	Brownish red.
Zinc sulphate.....	Light violet red.

It is very difficult to satisfactorily describe the shades produced, but distinct differences in color were apparent.

While the coloring matter or dyestuff may possess no direct value as a dyeing agent because of the cheaper and more available coal-tar dyes, it has been discussed principally for the reason that the tannin extract contains a considerable quantity of this substance and under the skillful manipulation of the tanner and the dyer it may be possible to produce tans of variable shades by the use of the different mordant solutions.

USE OF THE EXTRACT IN TANNING.

Partially to satisfy a desire to know whether the extract would be serviceable in the tanning of leather, a small quantity was submitted

to a commercial tanner for a practical test. The sample of leather tanned with the extract was fairly good in all general appearances. It was light reddish brown in color and was quite soft to the touch. It can not be said here whether this extract will compare favorably with some of the more common extracts, but from the test made and from the fact that it belongs to a class of tannins which are extensively used it does not seem unreasonable to suppose that it may find use in the leather industry, since a brisk and steady demand for tanning materials now exists.

AVAILABLE QUANTITY AND VALUE.

The quantity of seeds remaining after the removal of the pulp for the sirup and the extraction of the fixed oil would approximate 2,000 to 2,700 tons. This material is directly available for the preparation of tannin extract and as much as 16.5 per cent may be extracted from it. The total weight of dry tannin extract, therefore, which could be prepared is about 330 to 445 tons, or from 660,000 to 890,000 pounds annually. The value of the yearly output of this extract, roughly estimated, should be from \$19,000 to \$26,000.

MEAL:

The residue left after the extraction of the fixed oil and the tannin extract has been termed the meal and constitutes the greater portion of the by-product. It consists largely of protein, carbohydrates, and inorganic constituents, of which possibly the protein is of most importance. According to analysis the meal contains 1.94 per cent of nitrogen, which corresponds to 12.12 per cent of available protein. Other constituents have been determined as follows: Moisture 10.6 per cent, ash 2.4 per cent, crude fiber 43.2 per cent, nitrogen-free extract 30.5 per cent, and ether extract 1.2 per cent.

VALUE AS STOCK FOOD.

The utilization of the meal lies in its possibility as a stock food. The valuable constituents in stock foods are protein, carbohydrates, and mineral compounds. The protein comprises the nitrogen compounds present and is most essential for the formation of the nitrogen tissues and for the proper growth of the animal. Protein compounds are contained to a greater or less extent in practically all vegetable and grain foods which are used for stock feeding. The carbohydrates, in which are included crude fiber, starch, sugar, and gums, are also most essential as feeding stuffs and are present in all vegetable stock foods in varying proportions. The crude fiber or cellulose is present in large quantities in such feeding stuff as hay, straw, bran, and in the hulls of the various grains. Cellulose, while digested with difficulty, is considered to possess food value. The nitrogen-free extract

embraces starch, sugar, and some gums whose nutritive values are generally conceded. Practically all stock foods of value contain large percentages of nitrogen-free extractive which is readily digested and assimilated by the animal. Like the soluble carbohydrates, the ether extract or fat is an important fuel and fat-producing constituent of stock foods. Likewise, the mineral portion, or ash, of vegetable foods is also a necessary ingredient.

For the purpose of comparing the composition of raisin-seed meal with other stock foods, the following table has been compiled. Only four classes of stock foods are given, namely, hay, straw, grains, and hulls, as these most nearly correspond to the class of foods to which raisin-seed meal is most closely related. The figures represent the relative composition of the foods as given by Jordan.¹

TABLE IV.—*Comparison of raisin-seed meal with various feeding stuffs.*

Feed.	Moisture.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Ether extract.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Raisin-seed meal.....	10.6	2.4	12.1	43.2	30.5	1.2
Corn cobs.....	10.7	1.4	2.4	30.1	54.9	0.5
Oat hulls.....	7.3	6.7	3.3	29.7	52.1	1.0
Rice hulls.....	8.2	13.2	3.6	35.7	38.6	0.7
Buckwheat hulls.....	13.2	2.2	4.6	43.5	35.3	1.1
Cottonseed hulls.....	11.1	2.8	4.2	46.3	33.4	2.2
Peanut hulls.....	9.0	3.4	6.6	64.3	15.1	1.6
Oat straw.....	9.2	5.1	4.0	37.0	42.2	2.3
Rye straw.....	7.1	3.2	3.0	38.9	46.6	1.2
Wheat straw.....	9.6	4.2	3.4	38.1	43.4	1.3
Soy-bean straw.....	10.1	5.8	4.6	40.4	37.4	1.7
Timothy hay.....	13.2	4.4	5.9	29.0	45.0	2.5
Swamp hay.....	11.6	6.7	7.2	26.6	45.9	2.0
Alfalfa hay.....	8.4	7.4	14.3	25.0	42.7	2.2
Oats.....	11.0	3.0	11.8	9.5	58.7	5.0
Barley.....	10.9	2.4	12.4	2.7	69.8	1.8
Rye.....	11.6	1.9	10.6	1.7	72.5	1.7
Wheat.....	10.5	1.8	11.9	1.8	71.9	2.1
Corn.....	10.9	1.5	16.5	2.1	58.6	5.4
Buckwheat.....	12.6	2.0	10.0	8.7	64.5	2.2
Sunflower seeds.....	8.6	2.6	16.3	29.9	21.4	21.2
Cotton seeds.....	10.3	3.5	18.4	23.2	24.7	19.9

From a careful observation of the table it is evident that the moisture content of raisin-seed meal is much the same as in the various foods cited. In percentage of ash it corresponds more closely to the grains and is much the same as the hulls, with the exception of the rice and oat hulls. It is lower in ash content than the various hays and straws. In protein it greatly excels the hulls, hays, and straws, containing practically the same amount as the various grains. The high percentage of protein as compared with the various hays and straws should make the meal of considerable food value. The percentage of fiber is relatively high, while the nitrogen-free extract compares with that of the grain hulls mentioned. Since the meal contains

about 30.5 per cent of nitrogen-free extractive it is fairly rich in soluble carbohydrates, which are of importance as a nutritive food. The ether extract or fat of the meal compares favorably with that of the hays, straws, and grain hulls.

Since raisin-seed meal contains considerable protein, together with a fairly high content of ash, soluble carbohydrates, and fat, it should possess useful feeding value. If mixed with other foods to supply the deficiency of some of its constituents, a well-balanced ration for the feeding of stock could be made and the meal thus profitably utilized. It should also be of some value as a constituent of chicken feed, since considerable protein is required in chicken rations.

AVAILABLE QUANTITY AND VALUE.

After the extraction of the tannin and the fixed oil from the raisin seeds there would remain about 1,600 to 2,200 tons of meal. The annual output of the meal, roughly estimated for its stock-feeding value, would be approximately from \$16,000 to \$23,000. Its feeding value would, however, necessarily have to be determined by actual feeding experiments.

SUMMARY.

In the preceding pages it has been shown that four important commodities, namely, sirup, fixed oil, tannin extract, and meal, are capable of being made from the large quantities of grape and raisin seeds which result from the seeding of raisins and the manufacture of wine and grape juice in this country.

Commercially, the manufacture of the sirup could be accomplished with comparative ease and readiness. Owing to the solubility of the sugars in water, the process of preparation resolves itself into simple extraction and concentration. Comparatively small quantities of water are necessary to completely dissolve the sugary matter from the seeds. The washing could possibly be most readily accomplished in large centrifuges, while the saturated solution requires only to be evaporated to produce the sirup. As the most convenient form of concentrating, vacuum pans would be the most efficient and expedient.

A clear, transparent sirup, with the characteristic delightful taste and flavor of the raisin, can be produced from the sticky seeds. Its uses are many and should justify its production from this waste material.

The fixed oil has been mentioned as found in considerable quantity in the seeds of raisins and also in the seeds of grapes which occur as by-products in the manufacture of wine and of grape juice. After washing off the sugary matter and drying and screening the

seeds, they need only to be ground for the production of the fixed oil. Two methods of extraction are feasible—by pressure and by solvents. Hot extraction by means of hydraulic presses would possibly yield the maximum of fixed oil. Cold pressure, having a tendency to incompletely extract the oil, would leave more fat in the press cake. Extraction by means of solvents such as benzene, carbon bisulphid, or low-boiling gasoline, or preferably, carbon tetrachlorid or trichlorethane, is practiced commercially because of the more complete exhaustion than by pressure, especially of materials with low oil content. The use of carbon tetrachlorid and trichlorethane has been recommended because of the noninflammable, nonexplosive properties of these solvents, both of which have comparatively low boiling points and are easily recovered. They are also capable of being used again for the same purpose.

The clear, amber-colored fixed oil, useful in paint and soap manufacture, and possibly in other industries, is capable of being produced in large quantities from the waste seeds. The important application of the oil in commerce, coupled with the large output available annually, should justify its production.

After the preparation of the sirup and the extraction of the oil from the seeds, the extraction of tannin has been recommended. The production of tannin extract is practicable only in the case of raisin seeds, since wine residues are probably largely depleted of their tannin content. The tannin, being soluble in water, can be extracted in a practical way by boiling the meal in large digestion vats, the solution being transferred to vacuum pans for concentration to a moist extract. If a dry extract is preferred it can be obtained by simply allowing the moist extract to dry in the air.

The large quantity of tannin extract which can be produced from raisin-seed meal and which is well adapted for the tanning of leather becomes the third important commercial product capable of being made from raisin seeds.

The final residue, the meal, seemingly already exhausted of all its constituents of value, still possesses useful qualities. The stock-feeding value of the meal has been discussed and a comparison made with several standard stock foods. While possibly it is not equal to some of the standard press cakes and meals on the market, yet on account of its high protein content its usefulness as part, at least, of a stock-feeding ration can hardly be denied.

Issued March 19, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 277.

B. T. GALLOWAY, *Chief of Bureau.*

A BIOCHEMICAL STUDY OF THE CURLY-TOP OF SUGAR BEETS.

BY

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and Fermentation Investigations.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 6, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 277 of the series of this Bureau the accompanying manuscript entitled "A Biochemical Study of the Curly-Top of Sugar Beets," by Dr. H. H. Bunzel, Chemical Biologist, submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

The study of the oxidizing processes seen in the physiological and pathological behavior of living things has until recently suffered on account of the lack of a satisfactory method for accurately investigating these phenomena. With the recent development of improved means of studying these reactions, however, it has become possible to view these processes of plant and animal activity in a somewhat clearer light. The accompanying paper summarizes the results following the application of the manometric method to a study of an important and somewhat obscure condition of sugar beets. New light has been thrown not only on a number of features of the trouble itself but also on the oxidizing activities of the normal sugar beet. While these results do not establish the fundamental causes of the curly-leaf disease, they seem likely to introduce more fundamental considerations.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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A BIOCHEMICAL STUDY OF THE CURLY-TOP OF SUGAR BEETS.

INTRODUCTION.

The curly-top of sugar beets seems to have attracted notice first in California about 1898. It is characterized briefly by the following symptoms (Shaw, 1910):¹ An inward curling of the leaves, a distortion of the veins of the affected leaves, hairy roots, and checked growth. The menacing character of the disease has been pointed out in former publications of this Bureau (Townsend, 1908; Shaw, 1910), in which it has been shown to be responsible for great financial losses in the western beet districts, not only by stunting the growth of sugar beets but also by preventing the production of seed. The Office of Cotton and Truck Disease and Sugar-Plant Investigations has therefore undertaken a systematic study of this disease, looking toward the discovery of its cause and the means of prevention.

CAUSE OF THE DISEASE.

Concerning the cause of this condition, a great variety of opinions have been expressed. Soon after its appearance in California the Spreckels Sugar Co. secured the opinion of a number of American and European experts, whose views have been summarized and discussed at length by Linhart (1901). They attributed the trouble to one of the following causes: Hot winds, insufficient fertilization, insects, micro-organisms, irregular irrigation and rainfall, and unknown atmospheric peculiarities. While later it was shown that curly-top develops after the bite of an insect (Ball, 1911), the curly-top leafhopper (*Eutettix tenella*), nothing is known concerning the mechanism by which this effect is produced or concerning the abnormal processes set up in the plant.

OBJECT OF THE INVESTIGATION.

Mr. W. A. Orton, in charge of Sugar-Plant Investigations of the Bureau of Plant Industry, requested the writer to make a quantita-

¹ For complete references to the literature cited in the text by the author's name and the date of publication, see the list at the end of this bulletin.

tive study of the oxidizing enzymes of normal and curly-top beets. It was hoped that an extensive and accurate knowledge of the physiological behavior of healthy and unhealthy plants would throw light on the causes of the condition, as knowledge of these causes would bring the remedy for the trouble nearer.

FORMER WORK ON RÔLE OF OXIDASES IN PLANT DISEASES.

The advisability of studying the oxidizing enzymes in connection with pathological conditions in plants is also suggested by the work of others. Mr. A. F. Woods (1902), formerly of this Bureau, explained the mosaic disease of tobacco on the basis of disturbances in the oxidase mechanism. He invariably found a greater quantity of oxidases in the spotted leaves than in the normal ones. He further proved that this excess of the oxidases seriously interfered with the action of diastases in the leaves and in this way brought about disturbances in the metabolism of the plant. This theory was criticized by Hunger (1903, 1905). Sorauer (1908) in studying the leaf-curl of potatoes came to the conclusion that the color changes accompanying the disease are not due to fusaria, other fungi, or bacteria, but to disturbances in the enzymotic equilibria. These disturbances manifest themselves in increased sugar and starch formation and therefore furnish a favorable medium for parasites. The latter, then, according to Sorauer, are responsible for the gross symptoms of the malady.

Sorauer's conclusions are based largely on experiments by Grüss. Sorauer emphasized principally the greater intensity of the peroxidase reaction and the diminution of the oxidase and tyrosinase reaction in the diseased tubers as compared with the healthy ones. Concordant views were expressed by Pozzi-Escot (1905), who attributed a number of plant diseases to excess of oxidases, inasmuch as the latter destroy the other enzymes taking part in metabolism. Doby (1911) recently made measurements of the oxidases in healthy and diseased potatoes and found no relationship between the oxidase content and the state of health of the tubers. Later, carrying out the experiments on a larger scale, Doby (1912) confirmed in general Sorauer's hypothesis concerning the enzymotic disturbances in the leaf-curl of potatoes. His results, moreover, show that in the diseased potatoes oxidases, peroxidases, and tyrosinases are present in increased quantities. The problem of the etiology of this disease has been discussed at length by Appel and Schlumberger (1911). A great deal more work must be done on the oxidases of normal and leaf-curled potatoes before any definite conclusions can be drawn. It is the intention of the writer to study this question when opportunity arises.

RESULTS OBTAINED WITH GREENHOUSE MATERIAL IN 1911.

In the early spring of the year 1911 the oxidase contents of healthy and of diseased sugar beets grown in the greenhouse were compared. All of the plants were grown under nearly the same conditions. This became particularly evident among the healthy plants, which in size and appearance were very uniform indeed. The measurements were carried out on the leaves according to the method devised by the writer, the details of whose experiments are given in a previous bulletin (Bunzel, 1912). The results of those experiments are shown in concise form in Table I.

TABLE I.—*Oxidase content of healthy and diseased beets grown in the greenhouse.*

Experiment No.	Juice used.	Manometer readings expressed in centimeters of mercury.
1	Juice of normal beet leaves.....	1.16
2	do.....	1.07
3	Juice of diseased beet leaves.....	5.61
4	do.....	4.30
5	Juice of normal beet leaves.....	1.10
6	do.....	1.17
7	Juice of diseased beet leaves.....	2.72
8	Juice of normal beet leaves.....	1.19
9	do.....	1.21
10	Juice of diseased beet leaves (showing slight symptoms only).....	1.51
	Mean absorption in experiments with juice of normal plants (in terms of units, ¹ 0.166).	1.15
	Mean absorption in experiments with juice of diseased plants (in terms of units, ¹ 0.509).	3.54

¹ The unit chosen was an oxidase solution of such strength that 1 liter of it could bring about the oxidation of the equivalent of 1 gram of hydrogen (Bunzel, 1912, p. 40).

The determinations given in Table I show a very striking difference between the juice of the normal and that of the diseased beet leaves. In all of the experiments the oxidase content, as indicated by the changes in pressure in the manometer resulting from oxygen absorption by the pyrogallol in the presence of the juice, is markedly greater in the diseased than in the healthy leaves. The oxidase content of the normal leaves seems to be fairly constant, while the juice of the curly-top beet leaves shows wide variations. The leaves used in experiment 3 give about five times as high a figure as normal leaves, while the leaves chosen in experiment 10 show an increase of only 25 per cent above the normal.

It is very interesting to note that the deviation in oxidase content of the pathological leaves, as measured by the method used, runs parallel with the appearance of the leaves. The plants used in experiment 3 showed very marked signs of curly-top, the leaves being small and shriveled and the hairy roots abundant, while the dis-

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ceased beet used in experiment 10, which showed a relatively low oxidase content, though higher than normal, had only a slight curling of the leaves.

EXPERIMENTAL WORK.

Although these results are quite conclusive in showing the existence of differences in the oxidase mechanism of the healthy and diseased sugar beets grown in the greenhouse, it is not justifiable to apply these results to conditions in the field without further experimentation. Where sugar beets are grown on a commercial scale, an entirely different and widely varying environment prevails. A trip was therefore undertaken to Ogden, Utah, the center of an important district in Utah and southern Idaho, where about half a million tons of sugar beets are harvested every year. The writer spent the month of August, 1911, at the beet-sugar factory of the Amalgamated Sugar Co., where all of the experiments described in this paper were carried out. The main object of the experiments was to study variations in the concentration of oxidases in the fresh plants.

SHORT DESCRIPTION OF APPARATUS USED IN THE FIELD.

As has been shown (Bunzel, 1912), a constant-temperature chamber is required for all experiments of this sort. The thermostat heretofore used is not well adapted to transportation, being large and difficult to set up. A special air thermostat, more durable and more easily installed, was therefore built for these experiments, differing from the former one principally in simplicity of construction. The heating was done by lamps mounted in a circle behind the fan, and at the front of the box was a swinging door instead of a sliding one, as in the other apparatus. The necessary switches, condensers, and dry cells were all mounted in a special compartment at one end of the thermostat, separated from the warm chamber. The thermostat, which has been slightly remodeled since being used for these experiments, will be described in detail and illustrated in a later publication.

MATERIALS AND REAGENTS USED IN THE EXPERIMENTS.

The material used was obtained very largely from the gardens and fields of the temporary station of the Office of Sugar-Plant Investigations of the Bureau of Plant Industry at Ogden, Utah. The remainder was collected on various fields of sugar-beet farmers in that vicinity. Fresh material, collected within one or two hours, was used in all experiments. The method of preparing it has been described in a previous publication (Bunzel, 1912). After grinding the

plant in a meat chopper the juice was expressed through a piece of raw silk. In all of the experiments 8 c. c. of a 1 per cent solution of pyrogallol and 2 c. c. of the leaf juice were used with 1 c. c. of normal sodium hydroxid in the basket. The rate of shaking in all the experiments to be described was 5 excursions in 3.5 seconds, the magnitude of the excursions being 10 centimeters. The temperature during the experiments described was 40.5° C., remaining constant to 0.1 degree. In a number of cases samples of the ground material and of the juice were preserved for analysis.

OXIDASE CONTENT OF LEAVES, ROOTS, AND SEEDS¹ OF NORMAL, HEALTHY PLANTS UNDER DIFFERENT CONDITIONS.

SERIES 1, AUGUST 22, 1911.

Leaves of two types from normal, healthy beets were collected at 7 a. m. from the same patch of ground in Mr. Chandler's field—very large leaves 30 to 40 centimeters long and small ones less than 15 centimeters long. Oxidase apparatus Nos. 5 and 7 received the juice obtained from the small leaves, while Nos. 11 and 12 were used for the experiments with the large leaves.

TABLE II.—*Manometer readings obtained from juices of small and large leaves of healthy beets (series 1).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.			
			Small leaves.		Large leaves.	
			No. 5.	No. 7.	No. 11.	No. 12.
	<i>Minutes.</i>	<i>° C.</i>				
9.20 a. m.	0	40.2	0	0	0	0
9.40 a. m.	20	40.2	-1.20	-1.05	-.40	-.35
10.00 a. m.	40	40.3	-2.80	-2.30	-1.20	-.80
10.20 a. m.	60	40.2	-3.35	-2.80	-1.30	-1.00
10.40 a. m.	80	40.2	-3.40	-3.00	-1.30	-1.00
11.00 a. m.	100	40.2	-3.60	-3.15	-1.45	-1.10
11.20 a. m.	120	40.2	-3.60	-3.20	-1.50	-1.10
Mean for Nos. 5 and 7.			-3.40			
Mean for Nos. 11 and 12.			-1.30			
Activity of juice of small leaves (expressed in units, pyrogallol).			.400			
Activity of juice of large leaves (expressed in units, pyrogallol).			.184			

The agreement between the duplicates in series 1 is fair, but the difference between the oxidase content of the small and large leaves is striking. The small leaves are nearly three times as rich in oxidases as the large ones.

¹ Throughout this paper "seed" is used in the usual sense of a group of calyxes, each containing several seeds.

SERIES 2, AUGUST 8, 1911.

The plants were very young, with leaves only 2 to 7 centimeters long, collected in the garden adjoining the station on the west. They had been protected by means of muslin nets against infestation by insects and presented the appearance of perfectly healthy plants.

TABLE III.—*Manometer readings obtained from juice of very young healthy beets (series 2).*

Time of reading manometer	Time elapsed.	Manometer readings, expressed in centimeters of mercury, in apparatus—	
		No. 3.	No. 5.
	<i>Minutes.</i>		
9.30 a. m.	0	0	0
10.00 a. m.	30	— .75	— .40
10.15 a. m.	45	— .95	— .80
10.30 a. m.	60	— 1.20	— 1.20
10.45 a. m.	75	— 1.30	— 1.25
11.00 a. m.	90	— 1.30	— 1.20

Activity of juice of leaves (expressed in units, pyrogallol)..... 0.180

Series 2 shows that the leaf juice of the healthy plants had an oxidase content approximately equal to that found for beets grown in the greenhouse. (Table I.) The mean result obtained in six separate experiments on greenhouse material was 0.166 (pyrogallol); in the carefully protected and necessarily healthy material of the field garden it was a little higher, 0.180 (pyrogallol). As shown below, the normal plants grown under natural conditions in the field had a tendency to yield slightly higher results than the normal greenhouse plants.

Results on the large leaves described in series 1 are in harmony with those given in Tables I and III, the oxidase content being 0.184 (pyrogallol). The small leaves collected from plants in the immediate vicinity of the large-leaved ones showed an oxidase content very much higher, i. e., 0.499 (pyrogallol). Although these small leaves showed no sign of disease, they were not strictly normal (?), inasmuch as their growth had been inhibited. Accompanying this stunted growth there was an increase in the oxidase content.

All of the plants examined were not collected at the same time of day. Series 3 to 7 were carried out to determine what variations, if any, took place in the concentration of the oxidases in the leaves at different periods of the day. These experiments make it possible to interpret correctly the differences observed between the plants living under different physiological conditions, even when the leaves were collected at different times of the same day.

SERIES 3 AND 4, AUGUST 25, 1911.

Large leaves, 30 centimeters long, of uniform size, were collected on the sugar-beet farm adjoining the sugar factory on the east. The leaves were picked from two plants of similar appearance, termed in this experiment *a* and *b*.

In series 3, the leaves were collected at sunrise (6.10 a. m.); and apparatus Nos. 3 and 7 received the juice of the leaves of plant *a*, while Nos. 11 and 12 were used for plant *b*.

In series 4, the leaves were collected at sundown (7.15 p. m.); and apparatus No. 3 was used for plant *a*, while Nos. 5 and 7 were used for plant *b*.

TABLE IV.—*Manometer readings obtained from juices of large beet leaves collected at different hours.*

SERIES 3.—LEAVES COLLECTED AT SUNRISE (6.10 A. M.).

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury.			
		Plant <i>a</i> .		Plant <i>b</i> .	
		No. 3.	No. 7.	No. 11.	No. 12.
	<i>Minutes.</i>				
7.20 a. m.	0	0	0	0	0
7.45 a. m.	25	-1.10	-1.80	-1.70	-1.75
8.10 a. m.	50	-1.60	-1.30	-1.30	-1.40
8.30 a. m.	70	-1.90	-1.70	-1.50	-1.80
8.50 a. m.	90	-1.90	-1.70	-1.75	-1.80

SERIES 4.—LEAVES COLLECTED AT SUNDOWN (7.15 P. M.).

				No. 5.	No. 7.
8.30 p. m.	0	0	.....	0	0
8.55 p. m.	25	-1.00	.....	-1.90	-1.10
9.20 p. m.	50	-2.30	.....	-2.00	-2.00
9.40 p. m.	70	-2.90	.....	-2.70	-2.60
10.00 p. m.	90	-3.30	.....	-3.00	-2.70
10.20 p. m.	110	-3.30	.....	-3.20	-3.10

<i>Series 3.</i> —Activity of juice of leaves <i>a</i> (expressed in units, pyrogallol).....	0.259
Activity of juice of leaves <i>b</i> (expressed in units, pyrogallol).....	.256
<i>Series 4.</i> —Activity of juice of leaves <i>a</i> (expressed in units, pyrogallol).....	.468
Activity of juice of leaves <i>b</i> (expressed in units, pyrogallol).....	.453

SERIES 5, 6, AND 7, AUGUST 30, 1911.

Five large leaves, 25 centimeters long, from each of two plants (*a* and *b*) of similar appearance were collected in the field adjoining the factory on the east, shortly before sunrise (6 a. m.) in series 5, at 9.30 a. m. in series 6, and at 2.45 p. m. in series 7. Apparatus Nos. 3 and 5 received the juice of the leaves of plant *a*; Nos. 6 and 7 the juice of the leaves of plant *b*.

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TABLE V.—*Manometer readings obtained from juices of large beet leaves collected at different hours.*

SERIES 5.—LEAVES COLLECTED AT 6 A. M.

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury.			
		Plant a.		Plant b.	
		No. 3.	No. 5.	No. 6.	No. 7.
	<i>Minutes.</i>				
7.00 a. m.....	0	0	0	0	0
7.15 a. m.....	15	— .60	— .70	— .65	— .70
7.30 a. m.....	30	— 1.05	— 1.00	— 1.05	— 1.20
7.45 a. m.....	45	— 1.20	— 1.15	— 1.20	— 1.35
8.00 a. m.....	60	— 1.40	— 1.50	— 1.40	— 1.60
8.15 a. m.....	75	— 1.55	— 1.60	— 1.60	— 1.70
8.30 a. m.....	90	— 1.75	— 1.70	— 1.80	— 1.80
8.45 a. m.....	105	— 1.80	— 1.75	— 1.80	— 1.90

SERIES 6.—LEAVES COLLECTED AT 9.30 A. M.

10.00 a. m.....	0	0	0	0	0
10.20 a. m.....	20	— .80	— .70	— .75	— .75
10.40 a. m.....	40	— 1.20	— 1.30	— 1.35	— 1.30
11.00 a. m.....	60	— 1.50	— 1.60	— 1.50	— 1.50
11.20 a. m.....	80	— 1.65	— 1.70	— 1.70	— 1.60
11.40 a. m.....	100	— 1.80	— 1.85	— 1.85	— 1.80
12.00 m.....	120	— 1.80	— 1.80	— 1.90	— 1.90

SERIES 7.—LEAVES COLLECTED AT 2.45 P. M.

3.35 p. m.....	0	0	0	0	0
3.55 p. m.....	20	— .80	— .80	— .80	— .70
4.15 p. m.....	40	— 1.40	— 1.70	— 1.30	— 1.30
4.35 p. m.....	60	— 1.90	— 1.90	— 1.80	— 1.60
4.55 p. m.....	80	— 2.15	— 2.00	— 2.00	— 1.60
5.15 p. m.....	100	— 2.25	— 2.15	— 2.10	— 1.90
5.25 p. m.....	110	— 2.25	— 2.20	— 2.10	— 1.90

<i>Series 5.</i> —Activity of juice of leaves a (expressed in units, pyrogallol).....	0.256
Activity of juice of leaves b (expressed in units, pyrogallol).....	.266
<i>Series 6.</i> —Activity of juice of leaves a (expressed in units, pyrogallol).....	.259
Activity of juice of leaves b (expressed in units, pyrogallol).....	.266
<i>Series 7.</i> —Activity of juice of leaves a (expressed in units, pyrogallol).....	.319
Activity of juice of leaves b (expressed in units, pyrogallol).....	.288

As series 3 to 7 show, there is a marked and gradual rise in the concentration of the oxidases in the leaves of the same plant as the time of the day proceeds. As indicated by the determination of the solids and ash of the same samples (shown in Table XIX), there is a distinct parallelism between the quantity of oxidase and of solids in the samples. The atmosphere during the month of August, 1911, at and in the vicinity of Ogden was abnormally dry and hot, so that the intense transpiration on the part of the plant is easily explained.

Incidentally three experiments (series 8 to 10) were made to study the distribution of the oxidases in the beets.

SERIES 8, AUGUST 23, 1911.

An apparently healthy seed plant, 1.5 meters high, was collected at 7.30 a. m. in the garden adjoining the station on the east. This plant was fresh, green, and in excellent condition. Apparatus No. 3 received the juice of the root, No. 7 the juice of the midribs of leaves and pedicels, No. 11 the juice of the stem, No. 12 the seed juice, and No. 13 the leaf juice.

TABLE VI.—*Manometer readings obtained from juices of different parts of a single plant (series 8).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury, in apparatus—				
		No. 3 (root).	No. 7 (midribs and pedicels).	No. 11 (stem).	No. 12 (seeds).	No. 13 (leaves).
	<i>Minutes.</i>					
9.35 a. m.	0	0	0	0	0	0
10.00 a. m.	25	-.65	-1.10	0	-1.80	-.80
10.20 a. m.	45	-1.20	-1.30	0	-3.00	-1.50
10.40 a. m.	65	-1.20	-1.60	0	-4.00	-2.00
11.00 a. m.	85	-1.40	-1.75	-.10	-4.70	-2.40
11.20 a. m.	105	-1.35	-1.70	-.10	-4.50	-2.50

Activity of juice of roots (expressed in units, pyrogallol)	0.194
Activity of juice of midribs of leaves and pedicels (expressed in units, pyrogallol)	.245
Activity of juice of stem (expressed in units, pyrogallol)	.014
Activity of juice of seeds (expressed in units, pyrogallol)	.648
Activity of juice of leaves (expressed in units, pyrogallol)	.300

SERIES 9, AUGUST 26, 1911.

A healthy looking, seed-carrying plant grown under the same conditions as that in series 8 was used. It was cut at 7.30 a. m. Apparatus No. 3 was used for the leaves, No. 5 for the seeds, No. 7 for the upper third of the root, and No. 11 for the lower third of the root.

TABLE VII.—*Manometer readings obtained from juices of different parts of a single plant (series 9).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury, in apparatus—			
		No. 3 (leaves).	No. 5 (seeds).	No. 7 (upper third of root).	No. 11 (lower third of root).
	<i>Minutes.</i>				
9.40 a. m.	0	0	0	0	0
10.00 a. m.	20	-1.05	-2.00	-1.40	-.85
10.20 a. m.	40	-1.60	-3.50	-2.20	-1.80
10.40 a. m.	60	-1.80	-4.00	-2.20	-2.40
11.00 a. m.	80	-2.00	-4.10	-2.40	-2.70
11.20 a. m.	100	-2.00	-4.05	-2.30	-2.65

Activity of juice of leaves (expressed in units, pyrogallol)	0.288
Activity of juice of seeds (expressed in units, pyrogallol)	.583
Activity of juice of upper third of root (expressed in units, pyrogallol)	.331
Activity of lower third of root (expressed in units, pyrogallol)	.381

SERIES 10, AUGUST 18, 1911.

The plant used was of the same type as that used in series 8 and 9. It was collected at 9 a. m. Apparatus No. 3 was used for leaves, No. 5 for seeds, No. 6 for pedicels and midribs of leaves, No. 11 for stems, No. 12 for the upper half of the root, and No. 13 for the lower half of the root.

TABLE VIII.—*Manometer readings obtained from juices of different parts of a single plant (series 10).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury, in apparatus—					
		No. 3 (leaves).	No. 5 (seeds).	No. 6 (pedicels and midribs).	No. 11 (stems).	No. 12 (upper half of root).	No. 13 (lower half of root).
	<i>Minutes.</i>						
10.30 a. m.....	0	0	0	0	0	0	0
11.00 a. m.....	30	-1.20	-2.80	-1.00	- .10	- .90	-1.10
11.20 a. m.....	50	-1.55	-3.70	-1.15	- .15	-1.05	-1.35
11.40 a. m.....	70	-1.60	-4.05	-1.30	- .20	-1.00	-1.60
12.00 m.....	90	-1.60	-4.10	-1.20	- .15	-1.00	-1.65

Activity of juice of leaves (expressed in units, pyrogallol).....	0.230
Activity of juice of seeds (expressed in units, pyrogallol).....	.590
Activity of juice of midribs and pedicels (expressed in units, pyrogallol).....	.173
Activity of juice of stems (expressed in units, pyrogallol).....	.022
Activity of juice of upper half of roots (expressed in units, pyrogallol).....	.144
Activity of juice of lower half of roots (expressed in units, pyrogallol).....	.237

According to the last three experiments (series 8-10), there is a great difference in the oxidase content of different parts of the same plant. In the chlorophyll-containing portions of the sugar-beet plant the activity shows a parallelism with the intensity of the color. The seeds which are greenest generally lead. The oxidase content of their juice in these experiments ranges from 0.58 to 0.65 units (pyrogallol). The juice of the seeds, it is interesting to note, is darker than the juice of the other portions of the plant. The leaves follow with an oxidase content of 0.23 to 0.36 units (pyrogallol); the stem as well as its juice presents a pale green appearance and yields a value of 0.014 to 0.022 units (pyrogallol), while the somewhat darker pedicels and midribs have a juice with a higher oxidase content, i. e., of 0.17 to 0.25 units (pyrogallol). The results obtained on the roots confirm those obtained in earlier experiments. The lower part of the root gives a more active juice than the upper. The difference is not always marked, but in some cases (series 14) it becomes almost as 2 to 1. The activity of the juice of the upper part of the root is generally below that of normal leaves, but in some cases (series 9) somewhat exceeds it. The activity of the juice of the lower part of the root generally exceeds that of normal leaves

(series 9, 10, 14, 15, 16). In the plants where growth has been stunted for some reason, the roots show no marked anomaly of oxidase content; therefore the leaves always give a very much higher figure, as will be seen later. Series 11 was carried out to make certain that the very high oxidase content obtained for the seeds was not merely accidental.

SERIES 11, AUGUST 9, 1911.

Seeds were collected at 7.30 a. m. from a tall, healthy plant in the garden adjoining the station on the east. Six experiments were carried out.

TABLE IX.—*Manometer readings obtained from juices of beet seeds (series 11).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury, in apparatus—					
		No. 3.	No. 5.	No. 7.	No. 11.	No. 12.	No. 13.
	<i>Minutes.</i>						
10.30 a. m.	0	0	0	0	0	0	0
11.00 a. m.	30	-2.30	-2.00	-2.45	-1.90	-2.25	-2.30
11.20 a. m.	50	-3.20	-3.10	-3.40	-3.10	-3.10	-3.15
11.40 a. m.	70	-4.00	-3.90	-4.10	-4.00	-4.05	-4.20
12.00 m.	90	-4.20	-4.00	-4.10	-4.05	-4.00	-4.15

Mean reading obtained 4.08
 Activity of juice of seeds (expressed in units, pyrogallol)587

The results of this series also show the high oxidase content of the seeds as compared with the other parts of the plant.

OXIDASE CONTENT OF LEAVES AND ROOTS OF DISEASED PLANTS.

The relations in normal, healthy plants having been elucidated, a study of the oxidase contents of the leaves and roots of the diseased plants was then undertaken.

SERIES 12, AUGUST 22, 1911.

Curly-top beets and controls were collected on the large Government field, Wilson Lane, Utah, at 1 p. m. All the leaves, except the extreme outside ones, were affected. These outside leaves were quite large (25 to 30 centimeters long), while the infected inner leaves measured from 10 to 20 centimeters. Apparatus Nos. 4 and 5 received the juices of the insect-injured leaves, Nos. 7 and 12 were used for the healthy ones, while in Nos. 13 and 15 experiments were made with the juice obtained from the root.

TABLE X.—*Manometer readings obtained from juices of diseased leaves, healthy leaves, and roots (series 12).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.					
			Diseased leaves.		Healthy leaves.		Roots.	
			No. 4.	No. 5.	No. 7.	No. 12.	No. 13.	No. 15.
	<i>Minutes.</i>	<i>° C.</i>						
3.05 p. m.	0	40.0	0	0	0	0	0	0
3.25 p. m.	20	40.1	-1.10	-1.20	-.60	-.30	Lost.	-.25
3.45 p. m.	40	40.1	-2.25	-2.35	-.90	-.60	(¹)	-1.00
4.05 p. m.	60		-2.70	-2.60	-1.10	-.60		-1.30
4.25 p. m.	80		-2.70	-2.70	-1.10	-.95		-1.30

¹ Stopcock opened.

Activity of juice of curly-top leaves (expressed in units, pyrogallol)..... 0.398
 Activity of juice of large, healthy control leaves (expressed in units, pyrogallol)..... .144
 Activity of juice of curly-top beets (expressed in units, pyrogallol)..... .187

Series 12 shows the great divergence in the oxidase content of healthy and diseased leaves growing on the same plant. The small, curly-top leaves were nearly three times as active as the large normal ones. There seems to be no marked difference between the oxidase content of the roots of the healthy and of the curly-top plants, as is seen by comparing the figures of this experiment with those of series 8, 9, 10, and 13. The divergence between the oxidase content of the healthy and normal leaves and those whose growth has been stunted is not due simply to a difference in size, inasmuch as small but perfectly healthy leaves, as used in series 2, have a low oxidase content.

SERIES 13, AUGUST 21, 1911.

Curly-top plants with pronounced symptoms were collected at 7 a. m. from the large field of the temporary field station. The large outer leaves, which were apparently normal, were separated. Apparatus Nos. 5 and 11 received the normal, while Nos. 7 and 12 received the affected leaf juices. The activity of the roots was studied in Nos. 13 and 15.

TABLE XI.—*Manometer readings obtained from juices of normal leaves, diseased leaves, and roots (series 13).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.					
			Normal leaves.		Diseased leaves.		Roots.	
			No. 5.	No. 11.	No. 7.	No. 12.	No. 13.	No. 15.
	<i>Minutes.</i>	<i>° C.</i>						
10.30 a. m.	0	40.0	0	0	0	0	0	0
11.00 a. m.	30	40.1	-.50	-.70	-1.40	-1.00	-1.20	-.50
11.45 a. m.	75	40.1	-1.05	-1.40	-2.30	-2.40	-1.90	-1.30
12.00 m.	90	40.1	-1.20	-1.35	-2.50	-2.70	-2.20	-1.50
12.15 p. m.	105	40.1	-1.30	-1.35	-2.50	-2.80	-2.00	-1.50

Activity of juice of healthy leaves (expressed in units, pyrogallol)..... 0.191
 Activity of juice of curly-top leaves (expressed in units, pyrogallol)..... .381
 Activity of juice of roots (expressed in units, pyrogallol)..... .253

SERIES 14, AUGUST 24, 1911.

Stunted plants and large controls were collected on Mr. Chandler's farm at 1 p. m. No explanation could be found for the stunted growth of the small plants, which occurred isolated in the midst of a group of plants four to six times their size. In this experiment the upper halves of the roots were ground to pulp separately from the lower halves. No. 3 gives the activity of the leaves of the small plant, No. 5 the upper half of the root of the same plant, No. 7 the lower half of the root of the same plant, No. 11 the leaves of the large control plant, No. 12 the upper half of the root of the same plant, No. 13 the lower half of the root of the same plant.

TABLE XII.—*Manometer readings obtained from juices of stunted beets and well-grown beets (series 14).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.					
			Small, stunted plants.			Large control plants.		
			No. 3 (leaves).	No. 5 (upper half of root).	No. 7 (lower half of root).	No. 11 (leaves).	No. 12 (upper half of root).	No. 13 (lower half of root).
	<i>Minutes.</i>	<i>° C.</i>						
2.55 p. m.	0	40.1	0	0	0	0	0	0
3.25 p. m.	30	40.1	-1.50	-.60	-.75	-.90	-.80	-.70
3.45 p. m.	50	40.1	-2.20	-.70	-1.00	-1.00	-1.10	-1.50
4.05 p. m.	70	40.1	-2.40	-.60	-1.10	-1.40	-1.10	-1.70
4.25 p. m.	90	40.1	-2.50	-.60	-1.10	-1.40	-1.20	-2.00
4.45 p. m.	110	40.1	-2.55	-.60	-1.10	-1.40	-1.20	-2.00

Activity of juice of leaves of small plants (expressed in units, pyrogallol)	0.367
Activity of juice of upper half of root (expressed in units, pyrogallol)	.086
Activity of juice of lower half of root (expressed in units, pyrogallol)	.158
Activity of juice of leaves of large control plants (expressed in units, pyrogallol)	.201
Activity of juice of upper half of root (expressed in units, pyrogallol)	.172
Activity of juice of lower half of root (expressed in units, pyrogallol)	.288

The results given in Table XII show that the leaves of plants which are small without showing signs of the curly-top disease are richer in oxidases than the leaves of large healthy plants growing in their immediate vicinity. The lower half of the roots of both kinds is richer in oxidases than the upper half.

SERIES 15, AUGUST 25, 1911.

Stunted plants and large controls were collected on Mr. Chandler's farm at 9 a. m. The growth of small plants had been retarded by drought. The roots were cut into three parts of equal length and only the upper and lower thirds used in the experiment. Apparatus No. 3 received the leaf juice of the small plants, No. 5 the juice of the upper third of the small roots, No. 7 the lower third of the small roots, No. 11 the leaf juice of the large control plants, No. 12 the upper third of large roots, and No. 13 the lower third of the large roots.

TABLE XIII.—*Manometer readings obtained from juices of stunted beets and well-grown beets (series 15).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.					
			Small, stunted plants.			Large control plants.		
			No. 8 (leaves).	No. 5 (upper third of root).	No. 7 (lower third of root).	No. 11 (leaves).	No. 12 (upper third of root).	No. 13 (lower third of root).
	Minutes.	° C.						
10.30 a. m.	0	40.1	0	0	0	0	0	0
10.50 a. m.	20	40.1	-.90	-.20	-1.50	-.40	-.80	-.60
11.10 a. m.	40	40.2	-1.50	-.50	-2.30	-.80	-1.10	-1.30
11.30 a. m.	60	40.2	-1.60	-.90	-2.50	-.75	-1.15	-1.70
11.45 a. m.	75	40.2	-1.60	-.80	-2.90	-1.00	-1.20	-2.40
12.00 m.	90	40.2	-1.60	-.90	-2.80	-1.00	-1.20	-2.50

Activity of juice of leaves of small plants (expressed in units, pyrogallol).....	0.230
Activity of juice of upper third of root (expressed in units, pyrogallol).....	.130
Activity of juice of lower third of root (expressed in units, pyrogallol).....	.408
Activity of juice of leaves of large control plants (expressed in units, pyrogallol).....	.143
Activity of juice of upper third of root (expressed in units, pyrogallol).....	.170
Activity of juice of lower third of root (expressed in units, pyrogallol).....	.364

While there is no striking difference between the roots of the stunted and the normal plants, there is again a marked difference between the leaves of the two kinds of plants. The small leaves in this experiment show an increased oxidase content as compared with the normal leaves. In agreement with the preceding experiment, the lower portions of the roots are more active than the upper portions. To get further evidence on this point, series 16 and 17 were carried out.

SERIES 16, AUGUST 25, 1911.

Curly-top beets were collected on the large field of the station at 2 p. m. Both leaves and beets were very small, the leaves ranging from 4 to 12 centimeters in length, while the beets varied in weight from 100 to 200 grams each. Apparatus Nos. 3 and 5 received the juice of the leaves, Nos. 7 and 11 the juice of the upper third of the roots, and Nos. 12 and 13 that of the lower third.

TABLE XIV.—*Manometer readings obtained from juices of small diseased beets (series 16).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.					
			Leaves.		Upper third of roots.		Lower third of roots.	
			No. 3.	No. 5.	No. 7.	No. 11.	No. 12.	No. 13.
	Minutes.	° C.						
3.20 p. m.	0	40.2	0	0	0	0	0	0
3.40 p. m.	20	40.2	-1.30	-1.15	-1.20	-.50	-1.00	-0.80
4.00 p. m.	40	40.2	-1.80	-1.60	-1.60	-1.00	-1.80	-1.60
4.20 p. m.	60	40.2	-1.90	-1.80	-1.80	-1.20	-2.10	-2.10
4.40 p. m.	80	40.2	-2.00	-1.90	-1.90	-1.40	-2.50	-2.60
5.00 p. m.	100	40.1	-2.05	-1.90	-1.90	-1.70	-3.20	-3.20
5.15 p. m.	115	40.1	-2.10	-1.95	-2.00	-1.60	-3.30	-3.35

Activity of juice of leaves (expressed in units, pyrogallol).....	0.288
Activity of juice of upper third of roots (expressed in units, pyrogallol).....	.259
Activity of juice of lower third of roots (expressed in units, pyrogallol).....	.475

SERIES 17, AUGUST 26, 1911.

Curly-top beets were collected on one large field of the station at 1 p. m. Apparatus Nos. 3 and 5 received the juice of the lower fifth of the roots and Nos. 7 and 12 the juice of the top fifth.

TABLE XV.—*Manometer readings obtained from juices of diseased beet roots (series 17).*

Time of reading manometer.	Time elapsed.	Temperature at time of measurement.	Manometer readings, expressed in centimeters of mercury.			
			Lowest fifth of roots.		Top fifth of roots.	
			No. 3.	No. 5.	No. 7.	No. 12.
	<i>Minutes.</i>	<i>° C.</i>				
3.00 p. m.	0	40.1	0	0	0	0
3.20 p. m.	20	40.2	-.55	-.80	-.70	-.80
3.40 p. m.	40	40.2	-1.50	-1.50	-1.50	-1.30
4.00 p. m.	60	40.2	-2.30	-2.30	-2.10	-1.60
4.20 p. m.	80	40.2	-2.75	-2.70	-2.30	-2.00
4.40 p. m.	100	40.2	-3.40	-3.30	-2.30	-2.00
5.00 p. m.	120	40.2	-3.45	-3.50	-2.40	-2.00

Activity of juice of lowest fifth of the roots (expressed in units, pyrogallol)..... 0.504
 Activity of the juice of top fifth of the roots (expressed in units, pyrogallol)..... .317

Series 17, with the observations previously cited, shows that the concentration of the oxidases in the lower portion of the root is two to three times greater than in the upper portion.

SERIES 18 AND 19, AUGUST 3 AND 4, 1911.

Roots of curly-top plants that had been siloed over the previous winter were used in these experiments. The plants showed no symptoms in the season of the year 1910. Those used belonged to the type called "trotzer," i. e., they failed to develop a seed stem and failed entirely to flower. They also showed marked curling of the leaves. The plants were collected in the garden adjoining the field station on the east at 8 a. m.—on August 3 for series 18 and on August 4 for series 19. Apparatus Nos. 3 and 5 contained the juice of the leaves, Nos. 7 and 11 the juice of the roots.

TABLE XVI.—*Manometer readings obtained from juices of curly-top beet leaves and roots.*

SERIES 18.—COLLECTED AT 8 A. M. ON AUGUST 3.

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury.			
		Leaves.		Roots.	
		No. 3.	No. 5.	No. 7.	No. 11.
	<i>Minutes.</i>				
10.00 a. m.	0	0	0	0	0
10.30 a. m.	30	-1.10	-.80	-.40	-.65
11.30 a. m.	90	-2.10	-1.90	-.80	-.95
11.50 a. m.	110	-2.80	-2.70	-1.20	-1.35
12.10 p. m.	130	-3.40	-3.55	-1.50	-1.55
12.20 p. m.	140	-3.35	-3.55	-1.50	-1.45

SERIES 19.—COLLECTED AT 8 A. M. ON AUGUST 4.

	<i>Minutes.</i>				
10.30 a. m.	0	0	0	0	0
10.45 a. m.	15	-1.25	-1.00	-.50	-.60
11.00 a. m.	30	-1.65	-1.80	-.70	-.65
11.15 a. m.	45	-2.10	-2.35	-1.00	-.90
11.25 a. m.	55	-2.90	-2.80	-1.20	-1.10
11.45 a. m.	75	-3.10	-3.10	-1.30	-1.35
12.00 m.	90	-3.05	-3.15	-1.35	-1.20

<i>Series 18.</i> —Activity of juice of leaves (expressed in units, pyrogallol).....	0.496
Activity of juice of roots (expressed in units, pyrogallol).....	.216
<i>Series 19.</i> —Activity of juice of leaves (expressed in units, pyrogallol).....	.446
Activity of juice of roots (expressed in units, pyrogallol).....	.133

According to the results in both series 18 and 19 the leaves of the curly-top plants again show a higher oxidase content than was noted in connection with the healthy plants.

SERIES 20, AUGUST 5, 1911.

Curly-top plants collected at 7.30 a. m. in the garden adjoining the field station on the east were used. The roots of these plants had been siloed over winter and showed no symptoms of curly-top in the season of 1910. The plants had well-developed seed stems and carried seed. Apparatus Nos. 3 and 5 received the juice of the leaves, Nos. 7 and 12 that of the roots.

TABLE XVII.—*Manometer readings obtained from juices of curly-top beet leaves and roots (series 20).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury.			
		Leaves.		Roots.	
		No. 3.	No. 5.	No. 7.	No. 12.
	<i>Minutes.</i>				
10.45 a. m.	0	0	0	0	0
11.10 a. m.	25	-1.35	-1.50	-.80	-.60
11.30 a. m.	45	-2.10	-2.00	-1.30	-1.30
11.50 a. m.	65	-2.80	-2.75	-1.70	-2.00
12.10 p. m.	85	-2.85	-2.70	-2.20	-2.10
12.25 p. m.	100	-2.90	-2.70	-2.20	-2.30

Activity of juice of leaves (expressed in units, pyrogallol).....	0.403
Activity of juice of roots (expressed in units, pyrogallol).....	.324

Series 20 also shows that in curly-top seed-carrying sugar-beet plants the oxidase content is high. It seemed interesting to determine the oxidase content of plants showing the "trotzer" condition, but healthy and normal in other respects. Series 21 bears on this point.

SERIES 21, AUGUST 7, 1911.

The plants were "trotzer" beets, normal in other respects. They were collected on the eastern side of the field station at 12.30 p. m. Apparatus Nos. 3 and 5 received the juice of the leaves, Nos. 7 and 11 that of the roots.

TABLE XVIII.—*Manometer readings obtained from normal "trotzer" beets (series 21).*

Time of reading manometer.	Time elapsed.	Manometer readings, expressed in centimeters of mercury.			
		Leaves.		Roots.	
		No. 3.	No. 5.	No. 7.	No. 11.
	<i>Minutes.</i>				
2.30 p. m.	0	0	0	0	0
3.00 p. m.	30	-1.60	-1.25	-1.00	-1.10
3.30 p. m.	50	-2.30	-2.10	-1.60	-1.60
3.40 p. m.	70	-3.00	-3.10	-1.60	-1.55
4.00 p. m.	90	-3.15	-3.05	-1.70	-1.60

Activity of juice of leaves (expressed in units, pyrogallol)..... 0.446
 Activity of juice of roots (expressed in units, pyrogallol)..... .237

It appears then that the leaves of the plants which failed to develop seed, the so-called "trotzer" beets, also have an increased oxidase content. The increased oxidase content of the plants whose growth has been retarded is not simply due to the lack of development, but rather to inadequate development. The plants used in series 2 were smaller than those used in any one of the previous experiments, but they were small for natural reasons; there was every reason to believe that they would ultimately develop into large and healthy plants. The oxidase content of their leaves is approximately that found in the leaves of normal plants grown in the greenhouse or nearly that of healthy plants grown in the field.

The plants which were small because of retarded growth, on the other hand, show entirely different behavior. Their leaves have an oxidizing power two to three times as great as that of the normal plants. This is the case whether the retardation of growth is due to curly-top, to drought, to dwarfing from excessive irrigation, or whether the retardation is only a partial one, such as the failure to develop seeds and stems on the part of biennially grown sugar beets. It is therefore evident that the oxidase content is not a function of the size of the leaves, since small, normal young leaves have no more oxidase than larger, older normal ones. Small, stunted leaves, on the other hand, have an increased oxidase content independent of their size.

TABLE XIX.—Determination of solids, ash, and nitrogen in the samples of sugar beets collected.

Sam- ple No.	Condition.	Part of plant used.	Shape.	Place of collection.	Day of At- tachment.	Hour.	Solids in fresh material.				Ash.				Nitrogen.				Oxidases.	
							Soluble in alcohol.	Insoluble in alcohol.	Total.	In alcohol-soluble ma- terial, all-solids be- sides.	Dried.	All solids.	In alcohol- insoluble material.	Total, all-solids basis.	In alcohol-insoluble material.	All-solids basis.	Cane sugar, all-solids basis.	Green material.	R $\times$ 100	S
A	B	C	D	E	F	G	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	P. c.	Units.	
1	Curly-top; showed no symptoms last year; sliced over winter; "trotsen."	Leaves.....	Whole	Garden east of station.	3	8.00 a.m.	6.10	11.24	16.34	1.28	18.69	12.85	14.13	5.36	3.09	1.84	0.466	3.02		
2	do.	Roots.....	Cubes, 1 cm.	do.	3	8.00 a.m.	8.10	6.41	14.51	.895	8.85	3.90	4.90	.76	.335	37.49	.216	1.49		
3	do.	Leaves.....	Whole	do.	4	8.00 a.m.	4.10	11.04	15.14	2.18	21.20	16.46	17.04	4.91	3.58	1.19	.446	2.94		
4	do.	Roots.....	Cubes, 1 cm.	do.	4	8.00 a.m.	10.05	6.48	16.53	1.09	7.96	3.12	4.21	.90	.353	48.10	.153	1.11		
5	do.	Leaves.....	Whole	do.	5	7.30 a.m.	3.90	12.64	16.54	2.18	35.53	27.18	29.36	2.95	2.26	.41	.403	2.44		
6	do.	Roots.....	Pulp	do.	5	7.30 a.m.	9.40	6.56	15.96	.50	10.54	4.33	4.83	.53	.341	47.50	.334			
7	do.	do.	Juice.	do.	5	7.30 a.m.	1.06	1.06			45.33									
8	Apparently normal; sliced over winter; "trotsen."	Leaves.....	Pulp	do.	7	12.30 p.m.	3.80	14.47	18.27	8.04	24.04	19.08	22.12	4.27	3.38	.77				
9	do.	Roots.....	do.	do.	7	12.30 p.m.	9.20	2.09	11.29	1.33	11.09	2.06	3.36	1.07	.20	68.20	.446			
10	do.	Leaves.....	Juice.	do.	7	12.30 p.m.		8.74			32.38			5.60						
11	do.	Roots.....	do.	do.	7	12.30 p.m.		1.00			35.55									
12	Normal.	Leaves.....	Pulp	Next east of factory	15	8.00 a.m.	7.00	10.83	17.83	2.97	26.11	16.85	18.53	3.11	1.99	.84				
13	do.	do.	Juice.	do.	15	8.00 a.m.		7.04			33.58			2.94	.392	64.20				
14	do.	Roots.....	Pulp	do.	15	8.00 a.m.	15.50	6.29	21.79	.735	7.62	2.20	2.94	1.36						
15	do.	do.	Juice.	do.	15	8.00 a.m.		1.10			19.80	16.08	19.06	6.31	4.06	1.24				
16	do.	Leaves.....	Pulp	Chandler farm.	16	6.00 a.m.	3.00	9.55	12.55	3.98	24.70			1.42						
17	do.	do.	Juice.	do.	16	6.00 a.m.		6.88			24.70									
18	do.	Roots.....	Pulp	do.	16	6.00 a.m.		5.62			24.33									
19	do.	do.	Juice.	do.	16	6.00 a.m.		4.44			27.76	20.65	24.38	3.28	2.44	1.56				
20	Apparently healthy; carrying seed; sliced over winter.	Leaves.....	Pulp	Garden east of station.	16	10.00 a.m.	4.50	13.20	17.70	3.70	27.76	20.65	24.38	3.28	2.44	1.56				

21	do.	do.	Juce.	16 10.00 a.m.	9.08	37.42	4.92	4.27	.....
22	Roots	do.	Pulp	16 10.00 a.m.	11.15	18.98	45	1.89	46.45
23	do.	do.	do.	16 10.00 a.m.	1.76	33.83	4.47	3.87	.....
24	Leaves	do.	Pulp	17 7.30 a.m.	3.60	11.46	21.79	3.09	1.44
25	do.	do.	Juce.	17 7.30 a.m.	6.18	14.94	23.98	2.37	.....
26	do.	do.	do.	17 7.30 a.m.	7.40	13.26	23.66	1.08	48
27	Roots	do.	Pulp	17 7.30 a.m.	6.89	13.26	6.99	1.08	35.62
28	do.	do.	Juce.	17 7.30 a.m.	33.08	11.78	5.22	6.99	.....
29	Seeds	do.	Whole	17 7.30 a.m.	3.45	27.95	6.89	7.79	48
30	Leaves	do.	Juce.	17 7.30 a.m.	3.45	27.95	6.89	7.79	48
31	Pedicles and midribs.	do.	do.	18 9.00 a.m.	3.20	6.08	26.60	2.18	1.88
32	Upper half of roots.	do.	do.	18 9.00 a.m.	4.10	7.94	18.56	27.64	5.60
33	Lower half of roots.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
34	Curly-top.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
35	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
36	Large leaves	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
37	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
38	Small leaves	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
39	Plant with small leaves; otherwise normal.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
40	Curly-top.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
41	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
42	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
43	Large healthy plant.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
44	Upper half of root.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
45	Lower half of root.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
46	Small plants; retarded by excessive watering.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
47	Upper third of roots of No. 46.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
48	Lower third of roots of No. 46.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
49	Curly-top.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
50	Healthy seed-bearing plants.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
51	Large healthy plants.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
52	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60
53	do.	do.	do.	18 9.00 a.m.	3.84	9.08	18.56	27.64	5.60

CHEMICAL ANALYSIS OF SAMPLES COLLECTED IN THE FIELD.

As stated above, samples of diseased and of healthy sugar beets were collected and brought to Washington for analysis. When the juice was to be preserved 100 grams of it were mixed with 150 cubic centimeters of 95 per cent alcohol. In some cases it seemed desirable to preserve some of the pulp from which the juice had been expressed. Such pulp samples were weighed and preserved in wide-mouthed bottles with two volumes of alcohol. The moisture, ash, total nitrogen, and cane sugar were determined in most of the samples. Unfortunately, a few of them did not afford enough material to complete the analysis. The determinations of cane sugar, ash in the alcohol-insoluble material, and nitrogen were made by the Bureau of Chemistry, and the results are shown in Table XIX (p. 24).

The figures reveal no parallelism between the concentration of the other constituents estimated and the condition of the plant, apart from the oxidase content of the leaves. The increased concentration of oxidases in the plants of inhibited growth becomes apparent from the two columns R and S under "Oxidases." Column R gives the concentration of the oxidases in the juice of the leaves, expressed in terms of units (pyrogallol). The figures in column S are obtained by multiplying the units of column R by 100 and dividing by the percentage of solids in the particular sample (shown in column J). The data for oxidase contents were thus reduced to an "all-solids" basis in order to ascertain whether the variations in oxidase concentration in some of the cases were due to a variation in the moisture content of the samples. In samples 51, 52, and 53 these computations changed the entire aspect of an experiment. The oxidase content of the juice of leaves which increased from 0.26 to 0.31 units (pyrogallol) during the period from 6 a. m. to 2.45 p. m., in reality diminished to four-fifths of its value at 6 a. m. when expressed as a fractional part of all the solids present. The rise of oxidase content shown in series 13 and 14 would probably also vanish if results were reduced to the "all-solids" basis, but unfortunately no samples were collected in connection with these two series of experiments.

DISCUSSION OF RESULTS.

The experiments described in this paper corroborate the results obtained with curly-top sugar beets grown in the greenhouse (Bunzel, 1912). The leaves of the curly-top plants had an oxidase content two to three times as great as the healthy and normally developed ones. No marked differences, however, could be detected between the roots of the two kinds of plants. An abnormally high oxidase content of leaves was also shown in plants whose growth

had been retarded. When the plants were stunted either by excessive watering, by drought, or through unknown agencies, the oxidase content of the leaves was much higher than in normal and healthy plants. The increase in oxidase concentration in the leaves is not a mere function of their size, inasmuch as very young normal leaves do not exhibit this characteristic. If the condition of the plant is such that only one of its functions (as the development of seed in biennially grown beets) is inhibited, the oxidase content is also high. The most general conclusion to be drawn from these observations is that an abnormal retardation of growth in sugar-beet plants is accompanied by an increase in the concentration of oxidases in the leaves or a change in the juice of the latter by which the pyrogallol oxidizing oxidase becomes more active.

Such an increase in the power of the juice to bring about or hasten oxidation under pathological conditions has been observed before. Woods found it in connection with a disease of tobacco, Sorauer in connection with the leaf-curl of potatoes. Further investigation must show whether the oxidases which have been studied by the authors cited and by the writer are identical with or directly related to those which Palladin and his school find so important in the respiration of plants. If they are, it is probable that an increase in their concentration leads to increased combustion in the cells. One would then be tempted to look at such plants as in a state of "fever."

The moisture, ash, sugar, and nitrogen content of some of the samples examined show no parallelism between gross chemical composition on the one hand and the extent of the disease and the oxidase content on the other. Moisture determinations are essential where experiments on the same plant at different times of the day are to be compared. The oxidase content of the juice increases in the course of the day, but slightly diminishes when calculated on the basis of the total solids present. In general, it may be said that the results obtained on normal material are more irregular and somewhat higher than the results previously obtained on the normal greenhouse material.

The distribution of the oxidase accomplishing the rapid oxidation of pyrogallol through the sugar-beet plant was studied. All of the parts examined were active. The juice of the seeds had the greatest oxidizing power, the juice of the leaves and roots being next in activity. The lower portion of the root was more active than the upper portion, being sometimes twice as active. The juice of the pedicels and midribs was almost as active as the leaf juice. The stem furnished a juice feebler in activity than any other part of the plant. In the green parts of the plant there seemed to be a general parallelism between the oxidase activity and the depth of the green color.

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Issued April 2, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 278.

B. T. GALLOWAY, *Chief of Bureau.*

FLORAL ABNORMALITIES IN MAIZE.

BY

JAMES H. KEMPTON,

Assistant in Crop Acclimatization and Adaptation Investigations.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1913.

BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 25, 1912.

SIR: I have the honor to transmit herewith a paper entitled "Floral Abnormalities in Maize," by Mr. James H. Kempton, Assistant in Crop Acclimatization, and to recommend its publication as Bulletin No. 278 of the Bureau series.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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FLORAL ABNORMALITIES IN MAIZE.

INTRODUCTION.

Indian corn (*Zea mays*) belongs to a species which has no near relatives among either wild or cultivated plants. It has been under domestication for so long a period and has become so profoundly modified in structural characters that there is now much uncertainty as to its nearest affiliations. In its floral characters, particularly, the modifications have been so great that the structural analogies with other grasses have remained rather obscure. This is particularly true with respect to the pistillate inflorescence.

The study of abnormal forms and displaced parts is one of the best methods of tracing the evolutionary history of a plant. In *Zea mays* abnormal forms are of common occurrence, and it is seldom indeed that several distinct abnormalities are not found when even a few plants are carefully examined. They occur most frequently in varieties that have had little or no selection, probably because most abnormalities are in the nature of undesirable reversions and so have been suppressed in well-bred strains as the result of selection. They can be brought into expression again by inbreeding or by crosses between widely different types.

NORMAL INFLORESCENCE.

The following brief description of the normal inflorescence in maize will serve as a basis for indicating more clearly the nature of the structural abnormalities to be described in detail.

The spikelets of the staminate inflorescence occur in pairs, of which one spikelet is sessile and the other is stalked, except in *Zea hirta*, where there usually are six spikelets borne together, and all are sessile. Each spikelet bears two flowers, each of which is provided with a glume, a lemma, a palea, a lodicule, and three versatile 2-celled stamens.

The spikelets of the pistillate inflorescence are also borne in pairs, but on relatively short pedicels of nearly equal length, each pair being located in an alveolus. The paired spikelets are ordinarily

arranged in double longitudinal rows, the adjoining pairs alternating with each other. (Fig. 1.) At least one variety of sweet corn, and frequently individuals of all varieties, show exceptions to this rowed

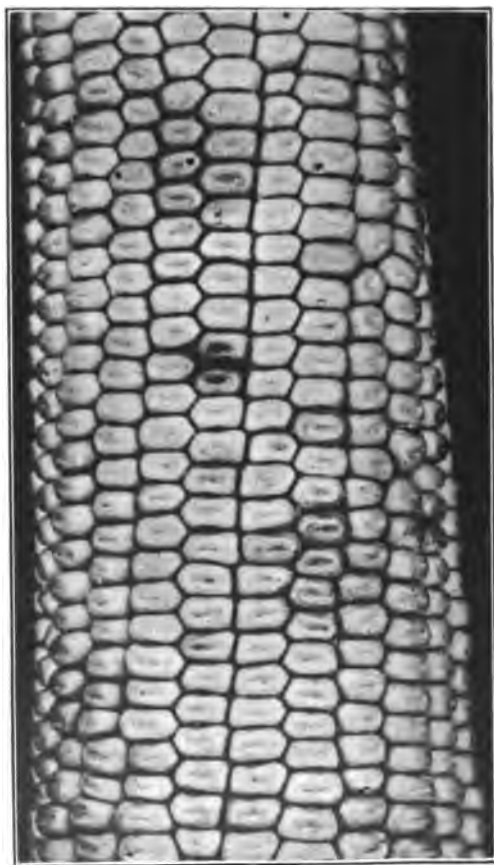


FIG. 1.—Section of an ear of maize, showing the arrangement of seeds. The straight line *B* is the division between opposite seeds representing the same pair of spikelets. The zigzag lines *A A* show the alternation between double rows of seeds that represent paired spikelets.

arrangement of the spikelets. In these exceptions the spikelets are arranged indiscriminately, bearing seeds usually of the “shoe-peg” type.

Unlike the staminate spikelet, the pistillate spikelet normally bears but one flower, the ovary of the second flower being completely aborted. The fertile flower develops into a seed of which the embryo is borne on the side toward the apex of the inflorescence. Like the staminate flower, each pistillate flower has a glume, a lemma, and a palea, but the lodicule, if it occurs, has never been observed. The bracts are much reduced in size in all except the pod corn (*Zea tunicata*), where they are greatly enlarged and entirely surround each seed.

The abortion of one of the flowers of the pistillate spikelet does not affect the development of its normal equipment of bracts. Consequently each seed is apparently equipped with six bracts, though as a matter of fact three of these bracts properly belong to the aborted flower.

ABNORMAL PISTILLATE SPIKELETS.

In a variety of corn grown by the Hopi Indians in Arizona it was observed by Mr. G. N. Collins that some of the kernels on the ear were apparently inverted; that is, instead of bearing the embryo on

the side of the kernel toward the apex of the cob it was borne on the side toward the base. It was first assumed that this inversion was due to a crowding of the kernels on the ear. Since then, however, a similar phenomenon has been observed in several other cases, one of which was in *Zea tunicata*. The dissection of an ear of this latter type suggested the true explanation. In this ear it was observed that in several instances both of the ovaries in a spikelet had developed into seeds. (See Pls. I and II.)

In these cases the kernels were always found back to back, with the inverted kernel always coming from the lower flower. This discovery on the ear of pod corn suggested that this was also the explanation of the other cases of inverted seeds which had not been dissected, owing to the difficulty of removing the spikelets entire. A few dissections of the inverted seeds in the Hopi variety were obtained on further trial, which showed in nearly every case that the spikelets had developed seeds from both flowers, the seeds from the lower flower being inverted.

In all the examples in which one inverted seed was found alone in the spikelet traces of the upper flower could be seen, showing that the inverted seed developed from the lower flower, the upper one being aborted.

In a large number of instances this development, two kernels on one spikelet, was accompanied by the abortion of both flowers of the other spikelet of the pair. This, however, was not always the case, as a few examples were found with two kernels in one spikelet and one in the other, and one case where all four flowers of the paired spikelets produced seed. (See Pl. II.) The kernels were usually of the same size, though cases were noticed where the seed from the lower flower was smaller. Both seeds germinate equally well and produce seedlings of nearly the same vigor.

The ear of *Zea tunicata* with inverted seeds was found among the ears harvested from a planting made in 1911. This ear had been fertilized with pollen from the Hopi variety. In a careful examination of 25 original ears grown by the Hopi Indians of Arizona 6 were found with inverted seeds. A single inverted seed was also found in an ear of a complex hybrid made up of varieties from China, Salvador, and Mexico. The greatest number of inverted seeds or 2-flowered spikelets found on any one of these ears was three, on one of the ears of the Hopi variety. In 1912 the ear of *Zea tunicata* that had been hybridized with the Hopi variety was planted to observe the frequency of the occurrence of the 2-flowered female spikelets. A critical examination of the 16 ears resulting from this planting failed to reveal any inverted seeds.

ABNORMAL STAMINATE SPIKELETS.

It was observed that among the plants there were several having a few female flowers in the male inflorescence. In these cases the ovary was produced in the upper flower of the sessile spikelet, the lower flower of this spikelet, as well as both flowers of the pediceled spikelet, remaining staminate. Most of the flowers which bore ovaries were perfect or nearly so, though the stamens were sometimes fewer than the normal number and were often sterile.

In all the cases observed where the stamens were fertile they were always three in number. Fertile stamens were never found in a flower having any sterile stamens; a flower either had fertile or sterile stamens, never both, and where fertile they were always of the normal number, three.

A few tassels bore on the lateral branches spikelets having two ovaries, one from each of the flowers. These were always in the sessile spikelet, the pediceled spikelet having both flowers staminate. This fact seems to indicate that the aborted spikelet which was found on the ear where two seeds had developed in the other spikelet of the pair probably corresponds to the pediceled spikelet of the pair.

Ilitis¹ has observed that the sessile spikelet in the staminate inflorescence of maize is the first to change in sex, but he does not go farther and state which flower of this spikelet is the first to undergo the change. The fact that the seeds developed from the lower flower are always inverted seems to indicate that it is the upper flower of the spikelet which normally changes sex first. The change would then take place in the upper flower of the sessile spikelet first, followed by the upper flower of the pediceled spikelet, then the lower flower of the sessile spikelet, and lastly the lower flower of the pediceled spikelet.

The sessile spikelets having two ovaries also had stamens, usually one or two, and rarely three, in each flower, but these were never fertile. Only a few of these 2-flowered female spikelets produced seeds, though all were well pollinated artificially. These seeds were always back to back, both germs facing out, though they were not borne longitudinally with respect to the rachis, one with the germ toward the tip and the other with the germ toward the base, as is the case where they are found on the ear.

INVERSION OF SEEDS ON THE EAR.

Included in the planting of experimental corn in 1912 were two rows of *Zea tunicata*. One row was from the same lot of seed which had in 1911 produced the one ear having inverted seeds. The other

¹ Ilitis, Hugo. Ueber einige bei *Zea mays* L. beobachtete Atavismen. *Zeitschrift für Induktive Abstammungs- und Vererbungslehre*, Bd. 5, 1911, p. 38-57.

row was from an ear of another strain that had been self-pollinated in 1911. None of the 16 ears of this latter strain grown in 1911 showed inverted seeds, nor did the original ear.

The seed from the strain that in 1911 produced the ear with inverted seeds had in 1912 tassels with a few inverted seeds, but showed no inverted seeds in the 30 ears that were produced.

The row from the self-fertilized ear of the other strain produced 30 plants, of which 8 had ears with inverted seeds, or 2-flowered spikelets. (See Pl. II.) Four ears were dissected and counts made of the number of 1-flowered and 2-flowered spikelets, the results being shown in Table I.

TABLE I.—*Number of female spikelets with one and two flowers.*

Plant No.	One flower.	Two flowers.
1.....	534	23
2.....	495	16
3 (ear 1).....	471	10
3 (ear 2).....	524	48

In three of these ears almost all of the 2-flowered spikelets were found within 10 centimeters of the tip of the ear. On the second ear of plant 3, however, the 2-flowered spikelets were well distributed throughout the entire ear.

The tendency for the ears of maize to bear a staminate spike is a well-known phenomenon. The occurrence of 2-flowered spikelets near the apex and the tendency for an ear to have a staminate spike may be taken as a general indication that the tip is less completely specialized. The fact that the second ear had more 2-flowered spikelets, as well as a more even distribution over the ear, is also in accordance with this view, as the ears tend to become more like branches with staminate tips as they near the base of the plant and are therefore more likely to vary in floral structure. Unfortunately, there was only the one 2-eared plant that had 2-flowered spikelets on the ears, so it was impossible to ascertain whether the behavior of the second or lower ear on plant 3 was merely due to chance or was of regular occurrence.

When the spikelets of the male inflorescence produce female flowers, a greater proportion of these spikelets produce two flowers than of those on the pistillate inflorescence. This would account for the occurrence toward the tips of the ears of more 2-flowered spikelets as the tips tend to become staminate, although staminate tips have never been found in pod corn.

OCCURRENCE OF SEEDS IN THE TASSEL OF POD CORN.

Several of the plants in the same row that produced the ears with 2-flowered spikelets also had greatly enlarged tassels which bore a large number of pistillate flowers. These plants produced no ears, but instead bore all their seeds in the tassel. Three of these tassels were dissected and counts made of the 1-flowered and 2-flowered female spikelets. It will be noticed that these tassels produced fully as many seeds as a fair-sized ear. The counts are shown in Table II.

TABLE II.—*Number of staminate spikelets with one and two pistillate flowers.*

Tassel No.	One flower.	Two flowers.
1.....	477	95
2.....	828	49
3.....	468	122

In tassel 1 there was one spikelet that had three well-developed seeds. This spikelet had the normal number of glumes, lemmas, and paleæ. This would seem to indicate that it was not a combination of two spikelets, as has been noticed in the staminate flowers where the number of glumes, lemmas, and paleæ are often more than the normal number. A tendency for the spikelets to become many flowered has often been noticed in the staminate flowers, where as many as 15 stamens have been found in one spikelet, the normal number being 6.

CONNATE SEEDS.

Another fact connected with the normally aborted ovary is that in many cases other than pod corn, when both seeds from the same spikelet develop, they are united back to back, making what resembles one seed with two germs on opposite sides. These connate seeds would be regarded as 2-seeded fruits if a strict botanical interpretation were given their structure, for they are inclosed in a single pericarp. The seed coat proper remains separate and only partially surrounds the individual seeds, penetrating the place of union for only a short distance and then disappearing completely. The corneous layer, which surrounds an amylaceous interior in most seeds of the dent type, only partially surrounds the amylaceous portion of these connate seeds. This amylaceous interior of the connate seeds is without any line of demarcation. (Fig. 2.)

The connate seeds are usually about twice the size of the single seeds on the same ear, though sometimes the seed developed from the lower flower is smaller. Unfortunately there were not enough connate seeds to determine the difference in weight between these and single seeds. The two halves germinated at about the same time and

produced seedlings of equal vigor. Here, too, the number of seeds available for the germination test was too small to determine definitely whether the seeds always germinate at the same time and have equal vigor.

The union of the seeds which develop from the 2-flowered spikelets appears to take place very early, since it is to be observed that the two styles or silks are usually united. (Pl. I, fig. 5.)

There have been no cases observed of two maize seeds growing together except where both have been produced by one spikelet. In pod corn the seeds produced in 2-flowered spikelets are never united, owing perhaps to the larger and earlier development of the bracts which surround each seed.

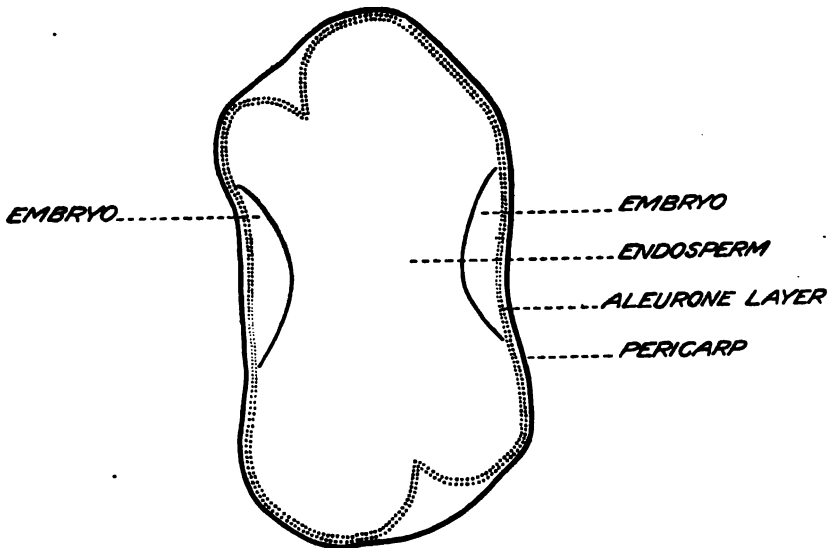


FIG. 2.—Diagram of a cross section of two connate maize seeds.

A large number of the seeds produced from 2-flowered spikelets in the Hopi variety were of the connate type, as were several from a Hopi $\times$ Mexican $\times$ Chinese hybrid. The union of the seeds was sometimes very striking when the two seeds differed in the color of the aleurone layer.

POLYEMBRYONY.

The connate kernels are an entirely distinct phenomenon from kernels with double embryos, two of which have been found by Mr. W. L. Goss, who has charge of the germination work of the Seed Laboratory of the United States Department of Agriculture. In these cases the kernels were of normal size and shape, but had exceptionally large germs, which produced two vigorous seedlings. The seeds with double embryos were not dissected, but were planted

in the greenhouse, as they were found in January. They were destroyed by worms between Saturday night and Monday morning, when the greenhouses were without care. Mr. Goss has found only two of these seeds in the many thousands he has germinated. There was no appreciable difference between the two seedlings, as will be seen in Plate I, figure 3.

EVOLUTIONARY SIGNIFICANCE OF ABNORMALITIES.

The origin of *Zea mays* is uncertain. It is believed by some botanists to have developed from an extinct group of grasses, while others believe it to be developed from a well-known group. It is within the limits of possibility that there are as yet undiscovered types able to multiply themselves and to exist in the wild state that are perhaps intermediate in form between *Zea* and its nearest known relative, *Euchlaena*. There can be little doubt that the varieties now commonly known would soon become extinct if left to reproduce themselves without the assistance of man.

We know that the aboriginal Americans grew corn with much less care than is now given to its culture, but with them it never reached its present efficiency in the yield of grain. It is evident that in increasing the efficiency of the maize plant the ability to hold its own in a wild state has been completely lost. It is not unreasonable to suppose that maize was much less difficult to grow 400 years ago, when the Europeans first began its culture. There probably is to be found among some of the isolated tribes of Indians in Mexico or Central America types of corn more nearly like the original wild plant upon which the first Indian culture was based. The methods of culture used by these isolated tribes have probably remained unchanged, though better forms may have arisen by unconscious selection and modified their primitive types.

The tendency of evolution is toward complicated types with more highly specialized parts. Sudden and abnormal changes are usually looked upon as reversions, while the development of new characters is attributed to the slower method of selection. Accepting this view, the frequent development of 2-flowered female spikelets on the pistillate inflorescence of *Zea mays* has a significant bearing on its uncertain evolution.

There is a striking resemblance in vegetative characters between *Zea mays* and certain members of the *Andropogoneæ*, but the normal floral parts are very different in structure and location. From the common abnormalities and variations in the floral organs of maize a continuous series can be arranged connecting the *Maydeæ* and *Andropogoneæ*.

The chief floral difference between the *Maydeæ* and the *Andropogoneæ* is that the *Andropogoneæ* normally have androgynous

flowers, while the flowers of the Maydeæ are usually unisexual. This difference, which has been used to divide the two tribes, is not fundamental as far as *Zea mays* is concerned. One species, *Zea tunicata*, commonly has plants that bear a terminal inflorescence composed of spikelets, a large percentage of which are perfect flowered. In other species of *Zea* adverse external conditions often result in androgynous flowers being produced in the male inflorescence. The character, which environment changes so essentially in form and which appears as a normal character in some of the plants of *Zea tunicata*, can hardly serve to keep *Zea mays* and some members of the Andropogoneæ separated.

Neither *Euchlaena* nor *Tripsacum* normally have 2-flowered female spikelets, though in both of these the male spikelets are 2-flowered, as in *Zea mays*. The examination of a large number of ears resulting from hybridizing *Euchlaena* and *Zea* revealed one inverted seed. In this case the upper flower of this spikelet was aborted, though traces of it could be seen.

From the fact that neither *Euchlaena* nor *Tripsacum* have 2-flowered female spikelets, we are led back into the Andropogoneæ, where the next nearest relatives are found.

Hackel, Goebel, and others have called attention to the close resemblance of *Zea mays* to certain members of the Andropogoneæ, chiefly on account of the frequent occurrence of androgynous flowers. The occurrence of 2-flowered female spikelets on the pistillate and staminate inflorescence, while less frequent than the occurrence of androgynous flowers, would seem to be of equal importance in strengthening the relation of *Zea mays* to the Andropogoneæ.

CONCLUSIONS.

Inverted seeds have been found on the male and female inflorescences of maize.

These inverted seeds are developed from the lower flower of the spikelet, which is normally aborted.

Flowers having ovaries and stamens always had the normal number, three, if the stamens were fertile.

Flowers having both ovaries and sterile stamens often had less than three stamens. Fertile and sterile stamens were never found in the same flower.

Spikelets with two ovaries never had any fertile stamens, but sometimes had from one to three sterile stamens.

The occurrence of a larger percentage of 2-flowered spikelets near the tip of the female inflorescence may be taken to indicate that the tip of the ear is less highly specialized than the remainder of the ear.

That there is a well-defined tendency for both male and female spikelets to become many flowered is evidenced by the fact that one

spikelet has been found with three seeds, and male spikelets with many more than the normal number of stamens are of common occurrence.

The development of two ovaries in one spikelet is not definitely correlated with the abortion of the other spikelet of the pair. A few cases have been found where four seeds have developed from the two spikelets of a pair and many pairs that have produced three seeds.

The development of two ovaries in one spikelet must be simultaneous, as a large number of cases have been found where the two seeds from one spikelet have grown together with a single pericarp. These connate seeds had been fertilized through a double silk which was attached to the pericarp near the union of the two seeds.

Connate seeds are a distinct phenomenon from single seeds with a double embryo, two of which have been seen.

The development of 2-flowered female spikelets is looked upon as a reversion to a more primitive type, the tendency of evolution being toward more complicated types with more highly specialized parts.

Neither *Euchlaena* nor *Tripsacum*, the two nearest known relatives of *Zea mays*, have 2-flowered female spikelets, and the occurrence of this character in maize is held to strengthen the relationship between *Zea* and the *Andropogoneæ*, already indicated by the occurrence of androgynous flowers.

PLATES.

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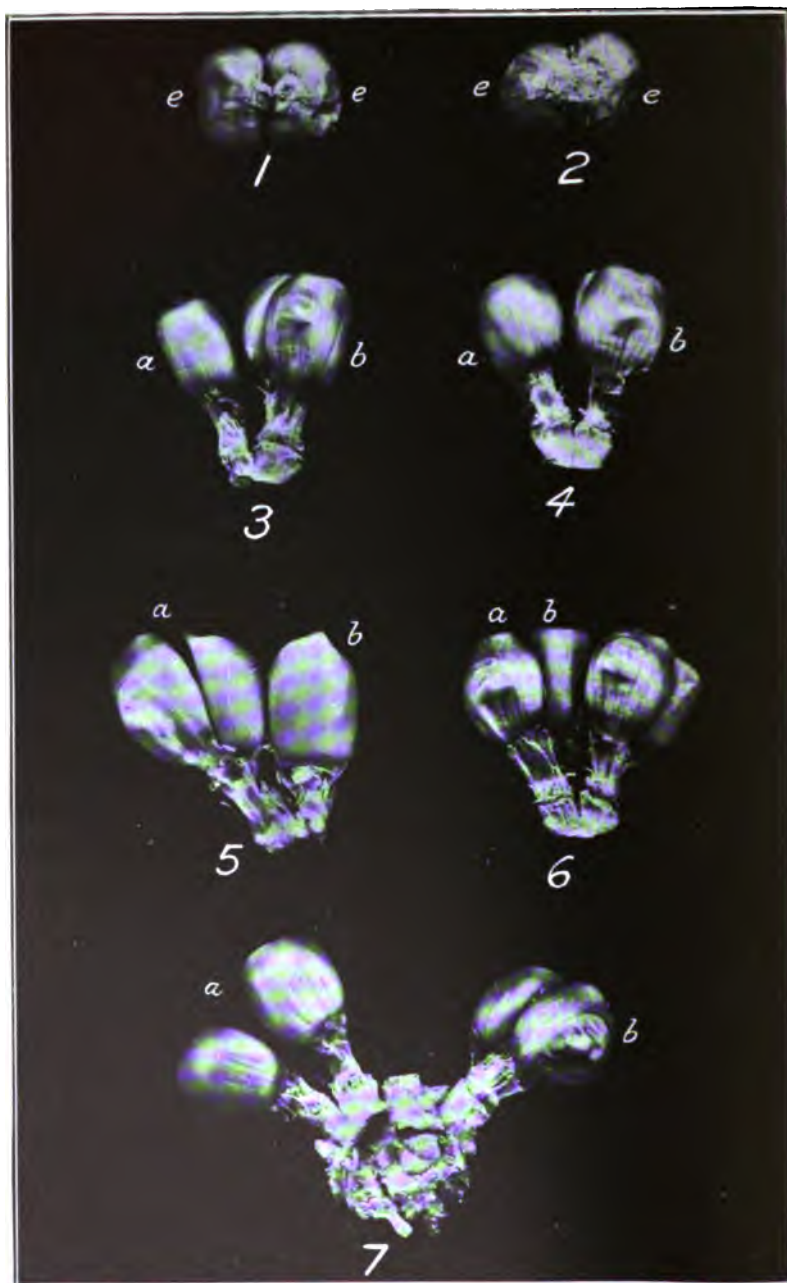
DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—Two seeds from a single spikelet showing equal development of the young seedlings. Fig. 2.—Germinated connate seeds showing equally developed seedlings from both germs. Fig. 3.—A polyembryonic seed from a commercial variety of maize. Fig. 4.—Paired spikelets from an ear of maize. It will be observed that one spikelet has remained sessile and pistillate, while the second spikelet has become pediceled and staminate. Fig. 5.—A group of connate seeds from an ear of the Hopi variety of maize. The ear from which these seeds were taken was grown by the Indians on their reservation in Arizona. In the center of the left-hand connate seeds, in the middle row, the place where the fasciated silk was attached is plainly visible. The pollen tubes which fertilized the two embryos must both have entered at this point. One half of these connate seeds was a bright yellow, while the other was a deep blue. It will be noticed that the division between the two members of these connate seeds is always diagonal.

PLATE II.—A group of seeds from an ear of pod corn (*Zea tunicata*). The four seeds in the upper row are from two spikelets. The embryos, it will be observed, are on opposite sides. The six seeds in the second row are from four spikelets. The two seeds on one stalk in each group are from one spikelet. The single seed on a stalk is from the other spikelet of the pair. This is also true of the three left-hand seeds in the third row from the top. The four seeds on the right hand of the third row from the top have developed from two paired spikelets, showing that the development of the lower flower into a seed is not always accompanied by the abortion of any of the flowers, though one spikelet of the pair is often aborted. The figure at the bottom shows a section of the cob with all but four seeds removed. The two seeds at the left are from spikelets, each on a separate stalk. The other two seeds at the right are both on one pedicel and one is inverted. These seeds both came from one spikelet and represent the upper and lower flowers. The seed on which the embryo is visible is from the lower flower.



FIG. 1.—TWO SEEDS FROM A SINGLE MAIZE SPIKELET. (NATURAL SIZE.) FIG. 2.—GERMINATED CONNATE SEEDS. (NATURAL SIZE.) FIG. 3.—A SEED WITH TWO EMBRYOS. (NATURAL SIZE.) FIG. 4.—PAIRED MALE AND FEMALE SPIKELETS FROM AN EAR OF MAIZE. (ENLARGED $1\frac{1}{2}$ DIAMETERS.) FIG. 5.—CONNATE SEEDS IN THE HOPI VARIETY OF MAIZE; *e* INDICATES POSITION OF EMBRYO. (ENLARGED $1\frac{1}{2}$ DIAMETERS.)



SEEDS FROM AN EAR OF ZEA TUNICATA.

Figs. 1 and 2.—Pairs of seeds each from a single spikelet; *e*, indicates position of embryos. Figs. 3 and 4.—*a*, One seed from a spikelet with germin toward apex of ear; *b*, two seeds from a spikelet with embryos on opposite sides. Fig. 5.—*a*, Two seeds from a single spikelet, both on one pedicel; *b*, a single seed from one spikelet. Fig. 6.—Paired spikelets which have each developed two seeds. *a*, Inverted seed developed from lower flower; *b*, seed developed from upper flower. Fig. 7.—Section of cob. *a*, Normal development of seeds from a pair of spikelets, each on a separate pedicel; *b*, two seeds from a single spikelet, both on a single pedicel. (Enlarged about 14 diameters.)

Issued April 16, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 279.

B. T. GALLOWAY, *Chief of Bureau.*

THE EFFECTS OF ARTIFICIAL SHADING ON PLANT GROWTH IN LOUISIANA.

BY

H. L. SHANTZ,

*Physiologist, Alkali and Drought Resistant
Plant Investigations.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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Editor, J. E. ROCKWELL.

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ALKALI AND DROUGHT RESISTANT PLANT INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., December 4, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "The Effects of Artificial Shading on Plant Growth in Louisiana," by Dr. H. L. Shantz, Physiologist, Alkali and Drought Resistant Plant Investigations, and to recommend its publication as Bulletin No. 279 of this Bureau.

This manuscript describes experiments with various crop plants which were grown under artificial shades of different degrees of density, the purpose being to determine the effect of diminished light intensity upon the growth of plants. In nearly every case a moderate reduction in the intensity of the light resulted in an increased growth as compared with plants of the same species growing in the open. It was also observed that in the case of lettuce the quality was improved by a moderate degree of shade. These results are obviously significant in relation to plant growth in the arid regions, where the light is normally much more intense than in Louisiana. Cooperative experiments of a similar nature are now in progress in Colorado, the object being to determine the importance of light as a factor in the physiology of drought resistance.

The experiments here described were conducted by Dr. Shantz at the University of Louisiana while occupying the chair of botany and bacteriology at that institution.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE EFFECTS OF ARTIFICIAL SHADING ON PLANT GROWTH IN LOUISIANA.

INTRODUCTION.

In physiological studies of drought resistance light is a factor which must not be overlooked. The energy received from the sun is largely consumed in transforming water to water vapor, and hence is directly responsible for much of the transpiration from plant surfaces.

The investigation described in the following pages was carried on in a humid region and was completed before the writer took up ¹ the investigation of light requirement in relation to drought resistance in the semiarid portion of the United States. Nevertheless, since practically the same methods of experimentation have been applied in both regions and since the results obtained in Louisiana have been found to be very useful for comparison with those obtained in Colorado, it is deemed advisable to publish the results of the earlier investigation, regarding it as complete in itself but closely related to work which is still in progress.

The experiments here described were conducted at Baton Rouge, La., during April and May, 1908. The purpose of the experiments was (1) to show the effect of different degrees of shade giving a definite series of light intensities on plant growth and (2) to show to what extent the so-called shade effects were independent of the resulting changes in other physical factors such as temperature and humidity.

The delay in publication ² of results has to a certain extent rendered them of confirmatory value only, since Lubimenko (1908)³ and Combes (1910) have covered part of the same ground in a very thorough way. Nevertheless, the experiments here described represent a distinct contribution to the subject, since the effects of shading are not the same in different localities, owing to differences in the initial or normal intensity of the light. The results are also of interest as affording indications of the comparative light requirements of a number of species not hitherto included in experiments of this

¹ In cooperation with Dr. L. J. Briggs, of the Office of Biophysical Investigations of the Bureau of Plant Industry.

² This delay was due to a desire on the part of the author to repeat the experiments before publication. Since this is now impracticable the results are published in the present form.

³ All references to literature are indicated in the text by the name of the author and the year of publication. For full citations, see the list at the end of this bulletin.

character and in indicating the minimum amount of solar energy required by these plants.

Six different plants and six different degrees of light intensity were used in the present experiments, which were so planned as to minimize the influence of the resulting changes in physical conditions other than light.

EXPERIMENTAL METHODS.

Two beds, A and B, 6 by 24 feet each, were prepared for seeding. On April 2, 1908, one row each of the following six plants was planted in each bed: Radish, French Breakfast; lettuce, New Orleans Improved Passion; potato, Triumph; cotton, Lee's; corn, St. Charles Red Cob; mustard, Bloomdale White.

As soon as the seedlings began coming through the soil each bed was covered with a framework over which cloths of different texture

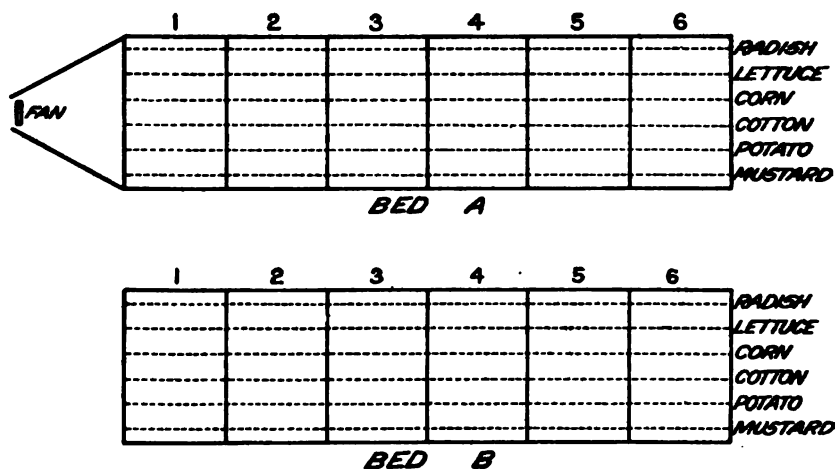


FIG. 1.—Diagrams of the beds and plantings.

(Pl. I, fig. 2) were stretched so as to give five different degrees of shades, the sixth section being left uncovered so as to receive full light. Each shade was 4 feet wide and was slightly inclined, resting about 2 feet above the beds on the south side and $2\frac{1}{2}$ feet above them on the north side. The beds had the long dimension east and west and were closed by boards on the sides and on the ends. The diagram (fig. 1) shows the arrangement, and the general appearance of the beds is shown in Plate I, figure 1.

Section 1 (east end) received the deepest shade and section 6 (west end) was left open to the full light. Since the shades were not separated by partitions, it will be seen that a small portion of the bed between each two shades was under the next deeper shade in the morning and under the next lighter shade in the afternoon. The result was that only the center of each section received the characteristic light reduction afforded by the corresponding shade, and there

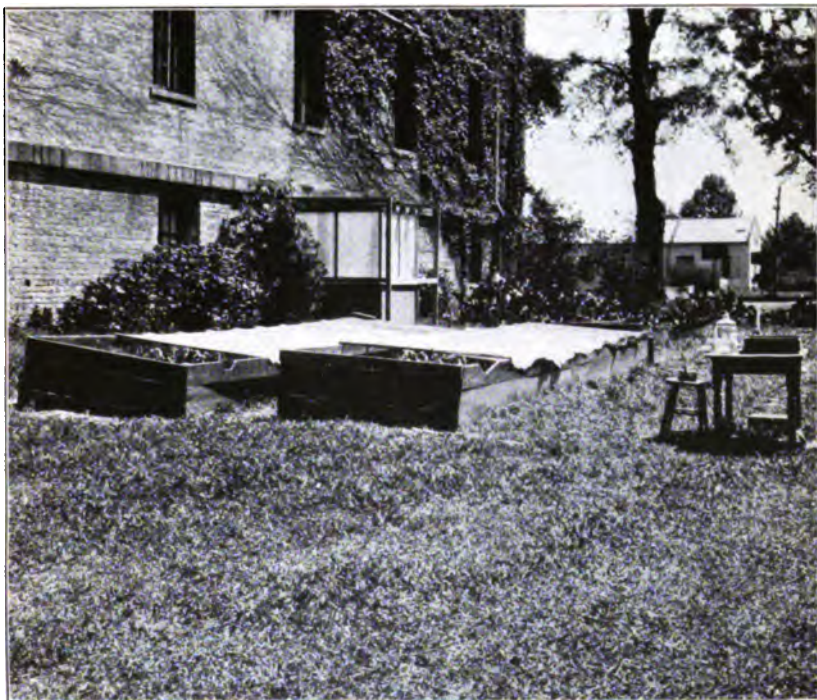


FIG. 1.—BEDS USED IN THE SHADE EXPERIMENTS AT BATON ROUGE, LA.: BED A AT THE RIGHT; B AT THE LEFT. THE LONG DIMENSION OF EACH BED IS EAST AND WEST.



FIG. 2.—REPRODUCTIONS FROM PHOTOGRAPHIC PRINTS, SHOWING THE TEXTURE OF THE CLOTHS USED ON SECTIONS 1 TO 5 AND INDICATING THE RELATIVE LIGHT PENETRATION.



FIG. 1.—GENERAL APPEARANCE OF COTTON PLANTS 30 DAYS AFTER GERMINATION IN BED A. SHADES AS NUMBERED; 1 INDICATES LEAST ILLUMINATION AND 6 NORMAL LIGHT.

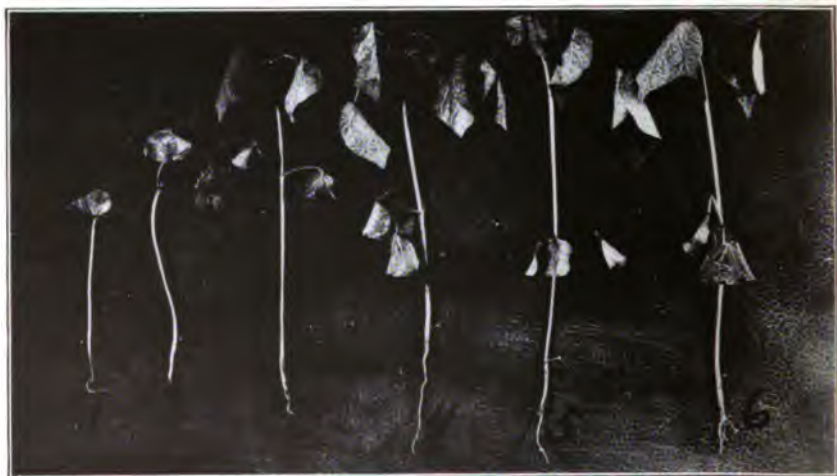


FIG. 2.—GENERAL APPEARANCE OF COTTON PLANT 30 DAYS AFTER GERMINATION IN BED B. SHADES AS NUMBERED; 1 INDICATES LEAST ILLUMINATION AND 6 NORMAL LIGHT.



FIG. 3.—RELATIVE GROWTH OF MUSTARD PLANTS AT THE END OF 24 DAYS IN BEDS A AND B. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).

was a complete gradation in light intensity from one section to another. At the east end of bed A a pointed extension of the board frame was built and an electric fan was placed in the small opening at the point (fig. 1). In this way outside air was constantly supplied during the day, and the effects of overheating, rise in atmospheric humidity, and change in water content of the soil in the deeper shades were reduced to a minimum. The other bed was covered in exactly the same way but without the extension, since no fan was used. At the back or north side of each frame a door was provided for taking observations under each different shade. The experiment was continued until May 23, or for a period of 51 days.

PHYSICAL CONDITIONS.

LIGHT.

At New Orleans, the nearest point at which light conditions are recorded by the United States Weather Bureau, the following is the record for April and May, 1908, the period of experimentation:

TABLE I.—*Record of light conditions at New Orleans, La., for April and May, 1908.*

Month.	Cloudy days.	Days partly cloudy.	Clear days.	Percentage of possible sunshine.
April.....	10	9	11	68
May.....	8	9	14	73

These measurements should indicate fairly well the conditions at Baton Rouge, which is only 70 miles distant.

In the measurement of the light reduction a photographic "printing-out" paper was used. The time required for this paper to reach a definite shade was recorded. The chief objection to be made to this method, as well as to the Wiesner (1907) method is that it measures only the chemical rays. But since the light which reached the plants passed through cloth, the amount of reduction is probably nearly the same for the heat rays as for the chemical rays. Moreover, the recent work of Kneip and Minder (1909) indicates that too great a distinction has been made in the effect of different wave lengths on photosynthesis. Consequently, where only relative intensities are to be measured, a "printing-out" photographic paper offers a ready means of comparing the degree of shade under different cloths. In the cooperative experiments above referred to Dr. L. J. Briggs and the writer have developed a method for measuring by means of the pyrliometer the relative transmission of energy by screens when placed normal to the sun's rays. The reduction of light by the cloth covers used in the Louisiana experiment has since been measured in this way by means of the pyrliometer devised by Abbot (1910), and

the measurements found to be in practical agreement with those made by means of the "printing-out" photographic paper.

The cloths designated in Table II were used and gave reductions in light intensity as indicated after each. The expressions n , $n/2$, $n/93$, etc., are convenient in referring to normal illumination, one-half normal illumination, one ninety-third normal illumination, etc.

TABLE II.—Sectional coverings and light intensities.

Section.	Cloth.	Fraction of normal light.
1.....	Black duck.....	$1/93$ or $n/93$.
2.....	Light canvas cloth (black)...	$1/15$ or $n/15$.
3.....	Chambray.....	$1/7$ or $n/7$.
4.....	Light chambray.....	$1/5$ or $n/5$.
5.....	Voile.....	$1/2$ or $n/2$.
6.....	No cover.....	1 or n .

Natural-size prints, made by placing the cloths used on the "printing-out" paper and exposing them to full sunlight, are reproduced in Plate I, figure 2. These prints show the texture of the different cloths and indicate their comparative efficiency in reducing light intensity.

TEMPERATURE.

Air temperatures under each section were read every day at 6 a. m., at noon, and at 6 p. m.; and a thermograph record was taken in section 1 of each bed. The temperatures of the soil at the surface and at a depth of 8 inches were read at the same time. It must be understood that the differences which would naturally result from

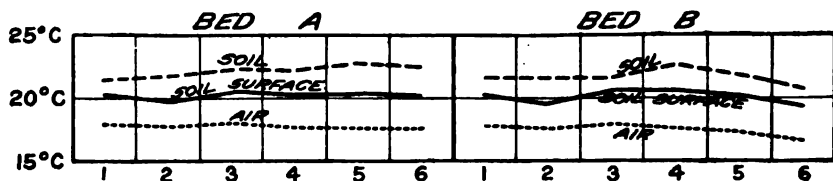


FIG. 2.—Diagrams showing temperatures at 6 a. m., averaged for the entire period of the experiments.

shading would not show markedly except at or near the period of maximum light. It is therefore evident that the morning and evening determinations should show only slight differences under the different shades.

The mean temperatures as recorded at 6 a. m. are shown in figure 2. There was no appreciable difference in the temperatures recorded in the two beds, nor for that matter under the different shades. The air temperatures averaged about 4°C . below the soil temperatures at the depth of 8 inches, and approximately 2°C . below the temperature of the soil surface. These results are due to the retention of a portion of the heat absorbed by the soil on the previous day.

The temperatures at noon showed some important differences (fig. 3). The temperatures of the soil surface were highest in the open air (sec. 6) and lowest in the deepest shade (sec. 1). The soil temperature was practically uniform in the bed without the fan. In the bed with the fan the soil temperature was relatively low in the deeper shades, probably as a result of increased evaporation due to the air movement.

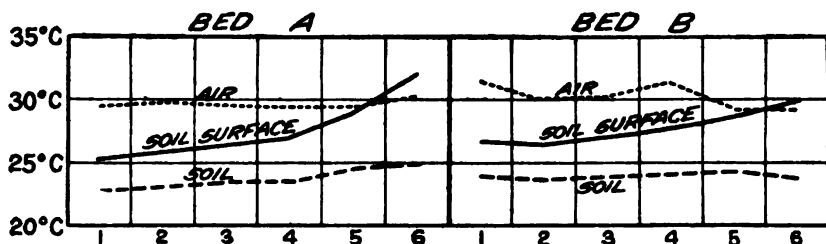


FIG. 3.—Diagrams showing temperatures at noon, averaged for the entire period of the experiments.

The air temperatures in sections 1 to 4 were noticeably higher in bed B than in the corresponding sections in bed A. These differences in air temperature were less clearly expressed in the averages for the entire period of the experiments than they otherwise would have been, because of the occurrence of a number of dark or rainy days. The absolute maximum temperatures of the air recorded at noon for the period of experimentation bring out clearly the fact that higher temperatures prevailed in the bed without the fan.

TABLE III.—Absolute maximum temperatures during the experiments.

Bed.	Section.					
	1	2	3	4	5	6
A (with fan).....	°C. 34.0	°C. 35.5	°C. 32.2	°C. 32.5	°C. 33	°C. 32
B (without fan).....	38.0	36.0	34.5	33.5	33	32

The important facts here shown are the comparative uniformity of air temperatures in all of the different sections of bed A, and the relatively great variation in bed B.

The temperatures of the air, of the soil at the surface, and of the soil at a depth of 8 inches at 6 p. m. show only slight differences (fig. 4). In bed A the temperatures of the soil at the surface and at the depth of 8 inches were comparatively low in the deeper shades, as a result of the wind movement and the increased evaporation caused by the fan.

The temperatures of bed A show remarkable uniformity in the different sections at all hours of observation. The only important differences are to be found in the slightly lower temperatures of the

deeper shades, due to the introduction of outside air by the use of the fan. It is clear that overheating in the deeper shades was completely overcome by this method.

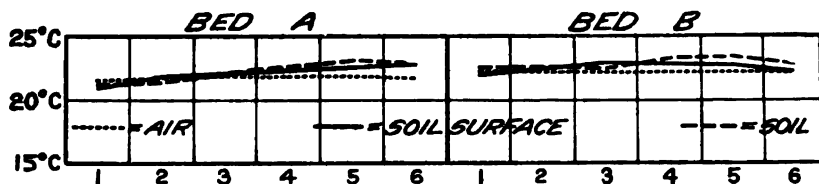


FIG. 4.—Diagrams showing temperatures at 6 p. m., averaged for the entire period of the experiments.

In bed B the differences were more marked, the most important differences having been the higher temperature of the air in the deeper shades.

SATURATION DEFICIT.

The saturation deficits recorded are shown in figure 5. The differences at 6 a. m. and at 6 p. m. were only slight. At noon the differ-

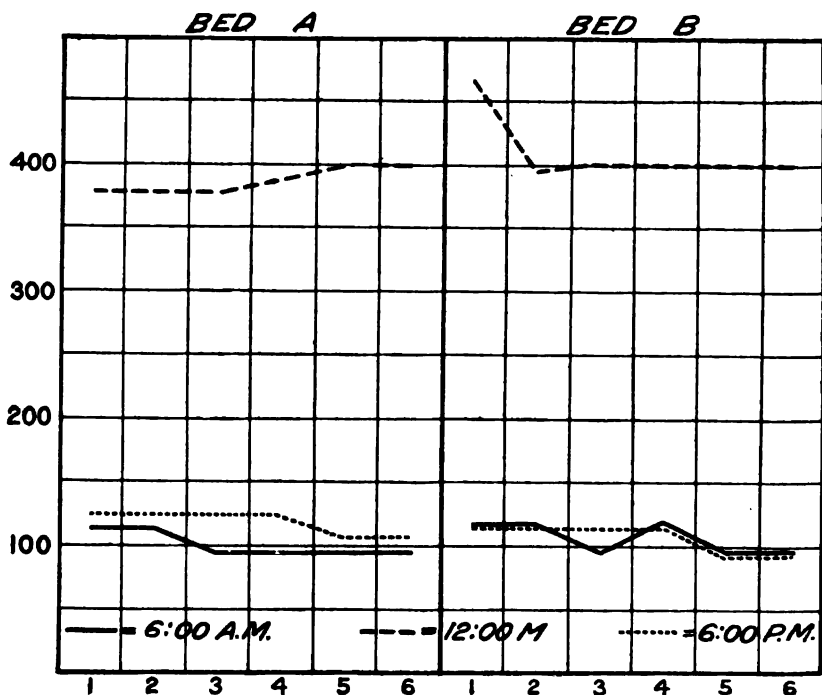


FIG. 5.—Diagrams showing the saturation deficit (in thousandths of an inch) at 6 a. m., at noon, and at 6 p. m., averaged for the entire period of the experiments.

ences between the two beds were very marked, the saturation deficits having been comparatively low in the deeper shades of bed A and comparatively high in the deeper shades of bed B. This high saturation deficit in section 1 of bed B was the result of the higher air tem-

perature. This difference in the relative evaporating power of the air in the different sections of bed B was very largely equalized in bed A as a result of the wind movement caused by the fan. Standardized porous cup evaporimeters somewhat similar to those devised by Livingston (1906) showed increased evaporation as a direct result of the increase in light (fig. 6), independent of the relative evaporating power of the air. It is also interesting to note that the increased evaporation from the porous cup in the sections under the deeper shades is due in bed A to the wind movement and in bed B to the higher temperature, while the increased evaporation in section 6 in both beds was due to a third factor—increase in intensity of illumination.

SUMMARY OF PHYSICAL CONDITIONS.

In regard to light, both beds A and B offered exactly the same range of conditions. In the two months during which the experiments were

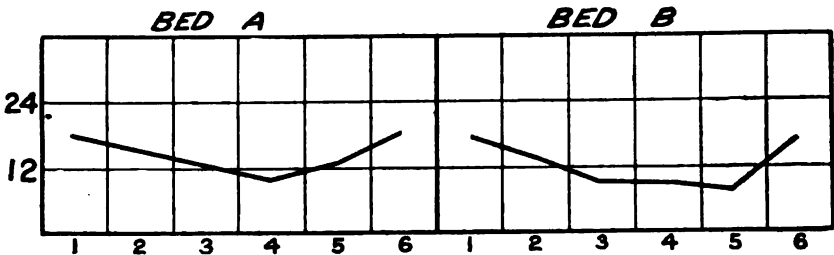


FIG. 6.—Diagrams showing the relative evaporation (in grams per day) from a porous cup for the entire period of the experiments.

conducted there was approximately 70 per cent of possible sunshine at the nearest station where observations were recorded.

The results show that a slight reduction in illumination is accompanied by increased growth. In the lighter shades the occurrence of dark days would reverse the conditions between such shades and full light by reducing the light of the shades below the optimum, thus overcoming to some extent the increase in growth of plants in these shades as compared with those in full light; but in the denser shades dark days would entirely stop growth, thus increasing the differences in growth between the denser shades and full light or the lighter shades. The illumination as shown by the recorded sunshine was fairly normal or, if anything, above the normal for this locality during the period of these experiments.

In bed A the use of the electric fan during the day to provide a current of air prevented entirely the changes in conditions of air temperature and humidity which otherwise result when shade is applied. In bed B all of the effects upon temperature and humidity resulting from altered light conditions were operative.

During the period of experimentation the rainfall was in excess of 21 inches and the problem of water supply was never of importance. Under all shades the soil was constantly in a moist condition, the samples taken for moisture determinations showing no differences of importance to plants. The soil was well drained.

In bed A the influence of the different shades was independent of their effects upon temperature and humidity, since these factors were neutralized by the use of the fan. Wind movement due to the fan was only slight, the movement having been less than 1 mile per hour in section 1 and entirely negligible in sections 3 to 6. In bed B the results under the different shades may have been influenced by the accompanying changes in temperature and humidity.

EFFECT OF DIFFERENT LIGHT INTENSITIES ON PLANTS.

MUSTARD.

In section 1 (n/93) the plants of mustard were unable to continue growth after the reserve food material in the seeds was exhausted. The light was too weak to enable the plant to elaborate carbohydrates. Growth ceased after about 25 days and the plants disappeared at the end of 30 days.

At the end of 30 days (Table IV), when the plants in section 1 (n/93) had died, no great reduction in growth was observable in the other sections with the exception of section 2 (n/15). In average height the plants (Table V) were comparatively uniform under the lighter shades at the end of 30 days. The diameter of stem (Table VI) varied considerably, being smallest in section 2 and much greater in the lighter shades. The stem diameter was not greatly increased in full light. In fact, while in bed A the stems in full light were slightly thicker than those under the shades, in bed B the stems showed considerably less diameter in the full light than in sections 4 and 5.

The general appearance of the plants at the end of 24 days is well illustrated in Plate II, figure 3. Growth in full light and in sections 3, 4, and 5 was approximately the same. In section 2 the plants were much dwarfed, while no plants were able to survive in section 1. No appreciable difference in the plants in beds A and B could be attributed to the air current of the fan and the resulting equalization of conditions of temperature and humidity under the different shades. Differences in light above one-seventh normal (n/7) seem to have had very little effect upon this plant.

At the end of the experiment, 51 days from the time of planting, the mustard plants showed the best growth between sections 4 and 5, or at light intensities between n/2 and n/5. When light

was reduced to $n/15$ or below no plants were able to survive. The mustard plants suffered severely from parasitic fungi, and on this account final weighing and measurements were omitted.

LETTUCE.

Lettuce was unable to elaborate any food material in section 1 and the plants died as soon as the reserve food material in the seeds had been consumed. In section 2 growth was barely possible and the plants were thin and emaciated at the end of the experiment. Lettuce could not continue growth where the light was reduced to less than $n/15$. In this respect it showed somewhat less shade tolerance than the mustard. In light more intense than $n/15$ no great difference was noted in the weight, although the plants were uniformly heavier in sections 3 to 5 than in normal light. (Table VIII.) In height plants 30 days old (Table V), as well as those 50 days old (Table

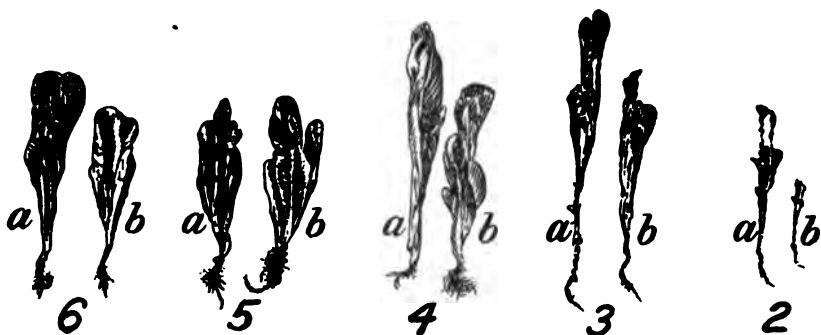


FIG. 7.—Relative sizes of lettuce plants 50 days after germination. The numbers correspond to those of the shades and the letters indicate the two beds in the experiment. (Traced from photograph.)

IX), were consistently taller in sections 3 and 4. The diameter of stem after 30 days (Table VI) and after 50 days (Table X) was not substantially increased in full light as compared with light reduced as little as to $n/7$. The stems in $n/15$ light were greatly reduced in diameter.

In figure 7 the relative size of the plants at the end of 50 days is shown. No consistent differences attributable to the differences in temperature and humidity could be noted as between bed A and bed B. In the deepest shade the plants died more quickly in the bed with the fan than in the bed without, but aside from this no other differences were noted.

Lettuce could not endure a shade greater than $n/15$. The best growth was made under the lighter shades. In full light the plants were smaller than in $n/2$ and $n/5$ light. Growth was best along the line between these two shades. In flavor only a slight change could be noted between the plants receiving full light and those receiving

n/2 light, but under n/5 illumination the strong taste had almost entirely disappeared. When the light was reduced to n/7 the flavor was even better, but the plants were by no means as desirable in habit of growth as in brighter light.

RADISH.

In n/93 light the radish continued for 30 days in bed B. In bed A all plants subjected to this reduction of light had died before this date. At the end of 50 days plants were still growing in n/15 light, although the growth was very slight. The shade tolerance of radishes is about the same as that of lettuce.

Growth was quite consistently better in n/2 and n/5 than in full light, the plants having been not only heavier (Table VIII) but taller (Table IX) and showing more nodes (Table XI). The plants in bed A seem to have been better than those in bed B according to measurements of height and weight, but observations at the end of the experiment failed to show any consistent difference.

General observations showed that the best growth of radishes took place in sections 4 and 5, and a decided reduction in section 3 and in full light. There was practically no production of roots below section 3. The effect of shade could not be noted in the flavor.

POTATO.

Because of the large amount of stored food material, potato plants were able to continue growth in the deepest shade for a period of 50 days. At the end of 30 days there was a noticeable difference in the height of the plants in the different shades (Table V), and by the end of 50 days the plants under shades which gave a light intensity varying from n/7 to n/2 became much taller than normal, especially those in bed A (Table IX). In diameter of stem there was little difference either after 30 days or after 50 days. (Tables VI and X.) In weight there was considerable variation after 30 days (Table IV), and even more after 50 days (Table VIII). The plants gained greatly in weight during this period in light n/2 to n/7, but in light n/15 the plants weighed less at the end of 50 days than at the end of 30 days. This loss is also indicated by the shrinkage of the diameter of the stem. The number of nodes developed was greater in light n/2 to n/7, and it is evident that the increased height was due to an increase in the number of nodes and not to greater length of the individual segments. The number of nodes developed did not differ greatly in full light and in light intensities of 1/15 normal or less. (Table XI.) The height of the plants was about the same in normal light as in a light intensity of n/15. (Tables V and IX.)

It should be noted that the plants in bed A (that in which the fan was operated) were much taller and heavier than those in bed B. (Tables IV, V, VIII, and IX.) Since the difference showed most markedly in shade 5, which was so far removed from the fan as to make it practically impossible to detect the air current, the writer is inclined to regard it as produced by some factor other than those especially considered in this paper.

The potato could elaborate no food material and in fact developed no leaves in the deepest shade. In $n/15$ light the leaves were very small, and no food material, or at least very little, was elaborated, since when once the plants had exhausted the reserve food supply there was no further increase in weight, the weights at the end of 50 days having been less than at the end of 30 days. With a light intensity varying from $n/7$ to $n/2$ growth was greater than in full light.



FIG. 8.—Relative sizes of potato plants 30 days after the beginning of growth. The numbers correspond to those of the shades and the letters indicate the two beds in the experiment. (Traced from photograph.)

The relative size of the plants after 30 days (fig. 8) and 50 days (fig. 9) shows the increased growths in light $n/2$ to $n/7$; also the limited growth in $n/15$ and $n/93$ light. As long as the food supply of the tuber was adequate to the needs of the plants they grew as well under the deeper shades as in the more intense light; but as soon as the food supply failed, it became evident that a light intensity of $n/15$ or less was insufficient for food manufacture. Small leaves, which were normally green developed in $n/15$ light, but apparently little or no starch formation could take place.

COTTON.

In some ways the results of shading cotton were more interesting than those obtained with any other plant. The weight of the cotton plants showed a considerable increase at the end of 30 days even in $n/15$ and $n/93$ light. In $n/7$ to normal light no great differences

were noticed. After 50 days, however, the greatest growth was recorded in $n/2$ light. In the full light great reduction was noticed in the weight of the plant in each case. It is especially interesting that cotton, which is supposed to be a sun-loving plant, was the only plant able to remain alive and in a healthy condition in light as weak as $n/93$ for as long a period as 50 days. The plants continued in $n/15$ light in both beds until the end of the experiment, although no appreciable increase in weight resulted.

In height the best growths recorded were in light of an intensity equal to $n/7$ or stronger. (Tables V and IX.) In $n/93$ and $n/15$ the plants were not noticeably taller at the end of 50 days than at the end

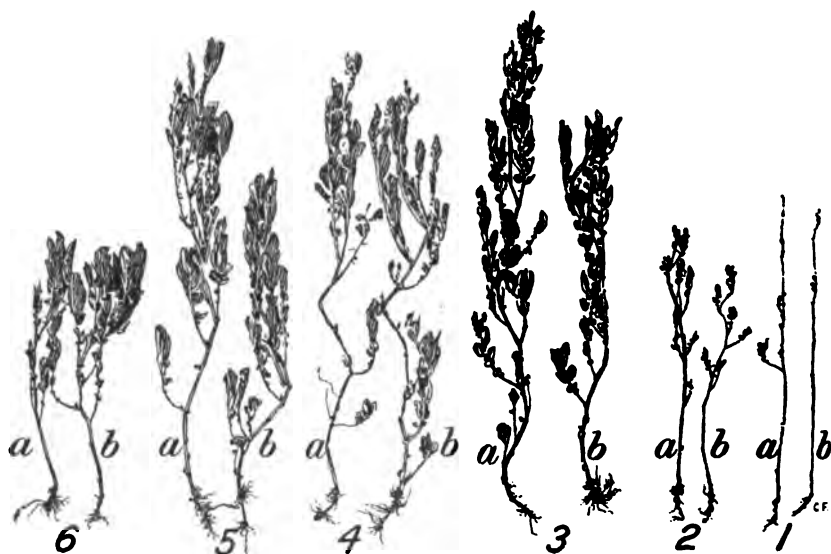


FIG. 9.—Relative sizes of potato plants 50 days after the beginning of growth. The numbers correspond to those of the shades and the letters indicate the two beds in the experiment. (Traced from photograph.)

of 30 days. In each case the height in normal light at the end of 50 days was less than in $n/7$ to $n/5$ light.

The relative diameter of stem is shown in Tables VI and X, and was usually greater in the weaker shades than in full light. A noticeable difference also occurred in the number of nodes developed at the end of 50 days, an increase in number having been observed in the weaker shades. (Table XI.)

A good idea of the appearance of the plants at the end of 30 days in the bed with the fan is given in Plate II, figure 1, and in the bed without the fan in Plate II, figure 2. No appreciable reduction in growth took place until the light was reduced below $n/7$. The relative size of the plants at the end of the experiment (after 50 days) is shown in figure 10.

At the end of the experiment no consistent effect could be noted which could be ascribed to the use of the fan. The best growth was found between $n/5$ and $n/2$ light, a marked decrease being noticeable in full light. In the shades no great reduction in growth occurred until the light was reduced to $n/15$, and even at the end of the experiment plants were alive and in good condition in $n/93$, although they had produced no leaves aside from the cotyledons. Cotton, therefore, showed more tolerance of shade than any of the other plants used in these experiments.

CORN.

Corn showed considerably more tolerance of shade during the early portion of the experiment than either mustard, lettuce, or radish,



FIG. 10.—Relative sizes of cotton plants 50 days after germination. The numbers correspond to those of the shades and the letters indicate the two beds in the experiment. (Traced from photograph.)

probably as a result of the larger seed and consequent greater food supply. At the end of 30 days plants were still living in $n/93$ light, and in bed A plants remained alive in $n/15$ until the end of the experiment, or 50 days. On the whole, however, the best plants were produced in the strongest light (Table VII), and in this respect the results with corn differ from those with cotton, potato, radish, lettuce, and mustard. While the plants were tallest in $n/7$ to $n/2$ light, the stems had the greatest diameter in the strongest light. The most interesting fact brought out in the case of corn was that although the plants grew fairly well with as slight illumination as $n/15$, and although with a light intensity of $n/93$ plants maintained themselves in the bed with the fan for 30 days, all plants had disappeared from the portion of the beds receiving this intensity of light before the end of the experiment, and in the bed without the fan they had also disappeared in $n/15$ light.

At the end of the experiment it was evident that corn was the least tolerant of shade of any of the plants used, and a reduction of light to $n/2$ caused a decided reduction in growth. Figure 11 shows the relative size of the corn at the end of the experiment.

In corn, as in the other plants, the differences due to differences in light intensity were much greater than those produced by the variations in other factors.



FIG. 11.—Relative sizes of corn plants 50 days after germination. The numbers correspond to those of the shades and the letters indicate the two beds in the experiment. (Traced from photograph.)

GENERAL CONDITION OF THE PLANTS AT THE END OF 30 DAYS.

The relative green weights based upon the average weight per plant at the end of 30 days under the different light intensities is shown in Table IV. The results for beds A and B show clearly that the growth was uniformly better in full light at this early period of the experiments. While the weights of some of the plants grown in the shades were above the weights of those grown in normal light, this was the exception rather than the rule. At the end of 30 days many of the plants were still growing even in the deeper shades, and at this time the green weights of the plants in most cases showed a gradual decrease from those in full light to those in $n/93$ light.

TABLE IV.—Average green weight per plant at the end of 30 days, in percentages of weight in normal light.

Bed and plants.	Section number and light intensity.					
	1, n/93.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Corn.....	2	8	30	55	77	100
Potato.....	34	65	168	130	129	100
Cotton.....	12	23	114	68	60	100
Radish.....	0	50	63	79	108	100
Mustard.....	0	16	69	72	70	100
Bed B (without fan):						
Corn.....	0	5	32	45	94	100
Potato.....	33	26	33	54	57	100
Cotton.....	12	31	49	123	92	100
Radish.....	0	88	48	77	68	100
Mustard.....	0	16	77	123	99	100

Table V shows the comparative height of the plants at the end of 30 days. The average height of the plants in the corresponding sections of beds A and B shows no significant differences. Both beds show clearly an increase in height in light n/7, n/5, and n/2 and a decided decrease in n/15 and n/93 light. In general the heights recorded in n/7, n/5, and n/2 light exceed those in normal light.

While the diameter of the stems (Table VI) of many plants is greater in shade than in full light, the averages show that, as a rule, the stem diameter was smaller in reduced light.

In general the plants showed a more or less gradual decrease in weight and in stem diameter in passing from normal to n/93 light. In height most of the plants in light n/7 to n/2 greatly exceeded those in normal light, and also those in n/15 to n/93 light. Plants of mustard and lettuce died in n/93 light, radish in n/93 light in the bed with the fan, and corn in n/93 light in the bed without the fan.

TABLE V.—Average height of plants at the end of 30 days, in percentages of height in normal light.

Bed and plants.	Section number and light intensity.					
	1, n/93.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Corn.....	38	48	86	113	104	100
Potato.....	120	149	149	160	131	100
Cotton.....	47	63	105	103	89	100
Radish.....	0	51	129	108	126	100
Lettuce.....	0	109	148	174	100	100
Mustard.....	0	57	102	108	102	100
Bed B (without fan):						
Corn.....	0	46	92	110	120	100
Potato.....	102	95	95	102	102	100
Cotton.....	47	68	105	100	111	100
Radish.....	36	54	88	125	123	100
Lettuce.....	0	96	169	169	130	100
Mustard.....	0	64	115	102	102	100

TABLE VI.—Average diameter of stem at the end of 30 days, in percentages of diameter in normal light.

Bed and plants.	Section number and light intensity.					
	1, n/93.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Corn.....	17	28	59	69	86	100
Potato.....	71	82	100	82	82	100
Cotton.....	72	91	127	109	109	100
Radish (diameter of root).....	0	17	33	33	117	100
Lettuce.....	0	60	110	130	125	100
Mustard.....	0	33	73	62	73	100
Bed B (without fan):						
Corn.....	0	32	59	62	90	100
Potato.....	71	82	71	71	82	100
Cotton.....	73	91	145	73	100	100
Radish (diameter of root).....	20	17	20	50	42	100
Lettuce.....	0	60	110	60	115	100
Mustard.....	0	33	91	127	127	100

GENERAL CONDITION OF THE PLANTS AT THE END OF 50 DAYS.

CORN.

During the later stage of the experiment corn behaved so differently from the other plants that it had best be discussed separately. In Table VII are shown the average green weight, the height, and the diameter of stem at the end of 50 days. These measurements indicate a reduction in the growth of corn even in the weakest shade. With a further reduction in light, marked reduction in growth is noted until in light n/93 none of the plants survived. Corn plants were barely able to survive in light n/15 and in bed B failed even under this illumination.

TABLE VII.—Growth of corn at the end of 50 days, in percentages of growth in normal light.

Bed and growth.	Section number and light intensity.					
	1, n/93.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Average green weight.....	0	35	47	84	62	100
Average height.....	0	87	111	87	108	100
Average diameter of stems.....	0	65	111	71	94	100
Bed B (without fan):						
Average green weight.....	0	0	7	46	94	100
Average height.....	0	0	72	96	103	100
Average diameter of stem.....	0	0	41	65	118	100

OTHER PLANTS.

In Table VIII the green weights at the end of 50 days are shown. An increase in weight is shown in five out of eight cases in n/7 light, as compared with that in normal light. The increase is considerably greater in n/5 light and still greater in n/2 light. A reduction of

light to $n/15$ reduced the weight many times, and at $n/93$ only potatoes and cotton remained alive. In general, no growth was made in light of an intensity equal to $n/15$ or less after the food supply in the seeds had been exhausted. As a rule, light intensities ranging from $n/7$ to $n/2$ produced heavier plants than normal light.

TABLE VIII.—Average green weight of plants at the end of 50 days, in percentages of weight of plants in normal light.

Bed and plants.	Section number and light intensity.					
	1, $n/93$.	2, $n/15$.	3, $n/7$.	4, $n/5$.	5, $n/2$.	6, n.
Bed A (with fan):						
Potato.....	28	44	282	139	238	100
Cotton.....	0	18	63	91	223	100
Radish.....	0	3	103	157	228	100
Lettuce.....	0	4	106	124	129	100
Bed B (without fan):						
Potato.....	23	27	160	250	146	100
Cotton.....	8	10	31	177	178	100
Radish.....	0	1	55	119	107	100
Lettuce.....	0	9	147	107	107	100

The tallest plants (Table IX) were produced under light intensities ranging from $n/7$ to $n/2$, while those in $n/93$ to $n/15$ were generally much shorter than in full light. The ratios between height in the various shades in which an increase was observed and height in normal light were not as great as were the ratios between weight in the shades in which an increase took place and that in normal light, which indicates that the plants under the weaker shades were heavier in proportion to their height than plants grown in normal light.

TABLE IX.—Average height of plants at the end of 50 days, in percentages of height in normal light.

Bed and plants.	Section number and light intensity.					
	1, $n/93$.	2, $n/15$.	3, $n/7$.	4, $n/5$.	5, $n/2$.	6, n.
Bed A (with fan):						
Potato.....	112	100	199	171	175	100
Cotton.....	0	66	108	130	133	100
Radish.....	0	52	165	178	126	100
Lettuce.....	0	91	145	136	97	100
Bed B (without fan):						
Potato.....	108	88	142	165	125	100
Cotton.....	32	38	122	108	130	100
Radish.....	0	26	96	117	117	100

The greatest diameter of the stem (Table X) was found in plants grown in the weaker shades, with one exception. With a reduction to $n/5$ or less, most of the plants showed a decided reduction in stem diameter.

TABLE X.—*Diameter of stem at end of 50 days, in percentages of diameter of stem in normal light.*

Bed and plants.	Section number and light intensity.					
	1, n/33.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Potato.....	53	67	93	80	107	100
Cotton.....	0	86	143	171	143	100
Lettuce.....	0	32	84	105	95	100
Bed B (without fan):						
Potato.....	80	67	80	93	80	100
Cotton.....	71	71	86	86	143	100
Lettuce.....	0	32	84	84	105	100

In number of nodes (Table XI) the plants grown in n/2 to n/7 light usually exceed those grown in normal light except for cotton in n/7 light. With a light reduction of n/15 or more the number of nodes produced was greatly reduced except in the case of potatoes.

TABLE XI.—*Average number of nodes per stem at the end of 50 days, in percentages of number developed in normal light.*

Bed and plants.	Section number and light intensity.					
	1, n/33.	2, n/15.	3, n/7.	4, n/5.	5, n/2.	6, n.
Bed A (with fan):						
Potato.....	84	103	168	161	136	100
Cotton.....	0	55	91	127	146	100
Radish.....	0	67	107	133	120	100
Bed B (without fan):						
Potato.....	97	91	116	148	123	100
Cotton.....	18	18	91	109	127	100
Radish.....	0	40	107	133	107	100

EFFECT OF SHADE ON THE THICKNESS OF LEAVES.

Leaf prints made by exposing a series of selected leaves for a sufficient length of time to produce a print on a photographic "printing-out" paper, give a very good idea of the relative absorption of light by the different leaves. Leaves which have developed in full light are thicker and give lighter colored or whiter prints than the thinner leaves which have been grown under shades.

In corn (Pl. III, fig. 2), though a slight difference can be noted as between normal (No. 6) and n/2 (No. 5) light, and a more marked difference as between n/2 and n/5 (No. 4), practically no difference can be noted in the shades of the prints from leaves produced under a light intensity of less than n/5. Only a comparatively slight difference is shown in this series of prints, which indicates that in corn there was only a slight modification in thickness of the leaf and density of the chlorophyll as a result of this variation in the physical environment.



FIG. 1.—LEAF PRINTS OF POTATO FROM ALL SECTIONS OF BEDS A AND B AT THE END OF 30 DAYS. SHADES AS NUMBERED; 1 INDICATES LEAST ILLUMINATION AND 6 NORMAL LIGHT.



FIG. 2.—LEAF PRINTS OF CORN FROM BEDS A AND B AT THE END OF 30 DAYS. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).



FIG. 1.—LEAF PRINTS OF LETTUCE FROM BEDS A AND B AT THE END OF 30 DAYS. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).



FIG. 2.—LEAF PRINTS OF MUSTARD FROM BEDS A AND B AT THE END OF 30 DAYS. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).

The potato leaf prints present a very uniform gradation, being lightest in the case of leaves produced under full light and darkest in those produced under the deepest shade. (Pl. III, fig. 1.) In the older leaves a marked difference was noted between those produced under light intensities of $n/2$ and $n/5$. The prints from leaves under $n/2$ were almost as white as those grown under full light, while those in $n/5$ were almost as dark as from the leaves grown in $n/7$ or below, which shows a comparatively great morphological variation as a result of changed conditions.

In cotton (Pl. V, fig. 1) there was a rather uniform gradation in darkness of the print, passing from full light to the deeper shades. The most marked difference occurred between normal (section 6) and $n/2$ (section 5) light. In the cotyledons this difference is not so marked as in the later leaves, but there is a great although gradual variation from $n/93$ to normal illumination. Cotton showed considerable morphological differences in both the cotyledons and the foliage leaves.

Mustard shows a very gradual although slight difference in the leaves in passing from $n/93$ to normal light. (Pl. IV, fig. 2.) This indicates but little ability to modify the leaf morphology to meet changed conditions.

Radish shows a marked difference in the leaves produced under normal light as compared with those developed under $n/2$ and corresponding differences under each deeper shade. (Pl. V, fig. 2.) The same is true of lettuce. (Pl. IV, fig. 1.) In each case profound morphological changes resulted from altered environmental conditions.

It is especially interesting to note that the leaf prints for a number of these plants indicate marked morphological differences such as have been noted in comparing sun and shade leaves of the same species (Stahl, 1883). Two of the plants used, corn and mustard, show little variation, and these plants are the ones which have proved the least productive in shade. All of the others—cotton, potato, radish, and lettuce—show pronounced variations or morphological adaptations, and these are the plants which have shown increased production when grown in shade.

GENERAL DISCUSSION.

Lubimenko (1908) showed clearly that in France a slight reduction of illumination produced an increase in the production of dry matter in the great majority of the plants tested. Shades giving only a slight reduction of light intensity were employed, and no attempt was made to equalize other conditions. The work of Combes (1910) is far more exhaustive and brings out the fact that some of the plants

were immediately retarded in growth by the application of shade. This was not true for the ordinary mesophytic plants but for such plants as *Salsola tragus*, *Amaranthus blitoides*, and *Atriplex canescens*, which are all xerophytic, sun-loving plants.

Most of the species used showed increased growth in shade. Combes (1910) concludes from his experiments that seedlings are more tolerant of shade than are adult plants. From the data obtained both by Combes and by the writer it appears likely that tolerance of shade is largely determined by the ability of the plant to manufacture food. If this be the case, seedlings, because of the food stored in the seed, would be expected to show much greater tolerance than adult plants, which are entirely dependent upon photosynthesis to support further growth.

The results of the experiments described in this paper make it seem probable that only during the periods of most intense illumination was a light intensity of $n/15$ sufficient to permit the elaboration of starches in any of the plants grown. (Pl. VI.) Moreover, none of the native plants which grew as weeds at the edge of the beds under the different shades were able to manufacture starch when the light intensity was below $n/15$.

It was also evident that where the illumination exceeded $n/15$ cotton, lettuce, potato, and radish were able to elaborate organic matter as readily as under full light.

Careful observation of the growth of these plants for the period during which the experiment was continued showed in practically all cases an increased growth where there was a slight reduction of the light intensity. A decided increase in growth could be noted in passing from normal to one-half normal light in all cases with the exception of corn.

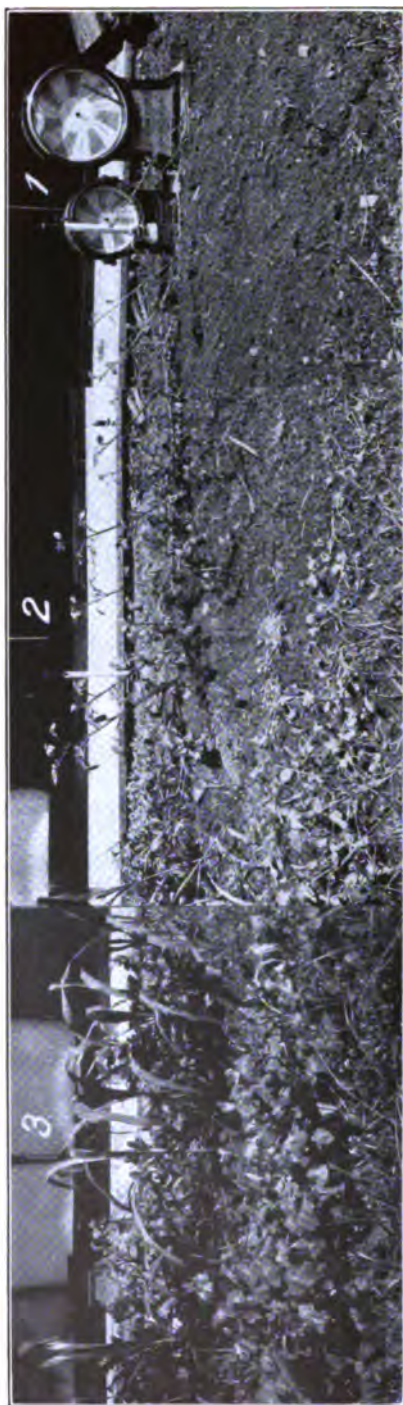
In general no reduction in growth occurred when light was reduced to $n/5$, and usually none took place at $n/7$. But when the light was reduced to $n/15$ a very marked falling off in growth occurred (Pl. VI) and in most species the plants disappeared entirely under the shade, giving an illumination of $n/93$. Mustard made its best growth in light of an intensity between $n/5$ and $n/2$, and radish between $n/7$ and $n/5$, with a decided reduction of growth in full light. Lettuce grew best where the light was between $n/2$ and $n/7$, the plants under full light being smaller by comparison. Cotton produced the largest and most vigorous plants between the shades corresponding to $n/5$ and $n/2$ light intensity, the plants in full light having been much smaller. In $n/15$ growth was almost checked, while in $n/93$ the plants continued alive but were unable to elaborate any food material. Full light seemed unfavorable to maximum growth in the potato but not in corn. While the potato and corn were able to maintain



FIG. 1.—LEAF PRINTS OF COTTON FROM BEDS A AND B AT THE END OF 30 DAYS. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).



FIG. 2.—LEAF PRINTS OF RADISH FROM BED B AT THE END OF 30 DAYS. LEAF PRINTS OF BED A EXHIBIT NO ESSENTIAL DIFFERENCES FROM THOSE HERE SHOWN. SHADES AS NUMBERED, RANGING FROM 2 (N/15 LIGHT) TO 6 (NORMAL).



GENERAL APPEARANCE OF BED A, SECTIONS 3, 2, AND 1 (N/7, N/15, AND N/93 LIGHTS), AT THE END OF 50 DAYS.

themselves in the deepest shade in the early part of the experiments, they made practically no growth in a light intensity of $n/15$ or less.

The effect of the reduction of light upon the flavor of lettuce was very marked. With a reduction to $n/5$ the flavor of lettuce was noticeably improved and the growth was still somewhat better than in full light. The flavor of radish was not perceptibly changed by shading.

The effect of the equalization of temperature, due to the introduction of the fan in one of the beds, was in most cases very slight. In the case of the potato the growth in the bed with the fan seemed to be considerably better than in the other. In all probability this was not due to the action of the fan itself, for the reason that in sections 4 and 5, far removed from the fan, the differences were greater than in sections 2 and 3, which were nearer to the fan. In fact, careful observations of the beds at the end of the experiment led to the conclusion that the effects resulting from changes in temperature, humidity, and even wind movement, were negligible as compared with those resulting from differences in illumination. As far as the evidence from these experiments go, the effects noted in shade experiments are attributable to reduction of the light intensity and not to any appreciable extent to the resulting differences in other factors.

In general, we may say that the growth of the plants with which experiments were made was not as good, measured by the general appearance of the plants, height, green weight, and number of nodes, in full light as it was in the light from $n/2$ to $n/5$. Some of these plants were able to grow in a light reduced to $n/7$ almost as well as in full sunlight. A reduction of the light to $n/15$ cut down the growth very perceptibly, although all of the plants, with the exception of corn in bed B, were able to keep alive even under this condition. When the light was reduced to $n/93$ the only plants which survived were cotton and potato. The potato plants were in a dying condition at the end of the experiment, and the cotton had made no growth, but was able to keep alive and in good condition even with this degree of shading. The probable reason for the failure of these plants to grow in light less than $n/15$ was their inability to manufacture carbohydrates. The plants were green colored and had developed chlorophyll, but were unable to increase in size after the reserve material of the seed or the tuber was exhausted. Corn showed very little ability to continue growth even with $n/15$ light. This amount of light reduction apparently marked almost the limit for carbon assimilation in all of the plants used.

The amount of solar energy utilized directly in the process of photosynthesis has been accurately calculated by Brown and Escomb (1905), and is a surprisingly small proportion of the amount of

light which in the present experiments proved to be necessary in order that growth could take place. They have also shown that of the incident light the greater portion is dissipated by emissivity from the leaves and through transpiration. A limit to the amount consumed in photosynthesis is therefore established by the limited supply of CO_2 in the atmosphere. Although only a fraction of 1 per cent of normal light is usually required for photosynthesis, it does not follow that photosynthesis will continue when the light intensity is reduced to this amount.

The actual amount of solar energy received by the plants under the different shades in the experiments here described necessarily varied greatly at different periods of the day. The maximum daily illumination would probably be the most important factor in fixing the lower limits for growth under the shades. By comparing the data given by Abbot (1911, pp. 358 and 385, fig. 72) it will be seen that the rate at which solar energy is received at Baton Rouge during the months of April and May during the brighter part of the day is approximately 150 calories per square meter per second, this value including both direct sunlight and the additional radiation from the sky (Abbot, 1911, p. 307).

Since the relative shading produced by the different cloths used in these experiments was measured by means of Abbot's pyrheliometer, it is possible roughly to express the results in terms of total solar energy received by the plants under different shades. In these experiments growth was best when the solar energy during the brighter part of the day was so reduced as to range from $n/2$ to $n/7$, or to range from 75 to 21 calories per square meter per second. On the other hand the lower limit of growth was somewhat below 10 calories per square meter per second ($n/15$). Previous measurements by Brown (1905, p. 525) show that photosynthesis was not retarded in some cases when the illumination was reduced to 7 calories per square meter per second. This accords very well with the results obtained in the experiments here recorded.

SUMMARY.

(1) When the illumination was so decreased as to range from $n/2$ to $n/7$ a general increase in growth resulted in potato, cotton, lettuce, and radish, which was expressed in increased green weight, height, and number of nodes.

(2) Corn made its best growth in full light.

(3) When the light was reduced to $n/15$ or less none of the plants tested were able to elaborate food material sufficient to produce growth after the seedling stage was passed.

(4) From Abbot's measurements, the total maximum rate at which solar energy was received during any considerable period while the experiment lasted was probably approximately 150 calories per square meter per second. In terms of solar energy, growth was best when the energy received varied from 21 to 75 calories per square meter per second. Photosynthesis and consequently growth practically ceased when the energy was reduced to 10 calories per square meter per second or less.

(5) The apparent tolerance of shade exhibited by the younger plants was probably the result of the food supply still remaining in the seed and not of any special ability of seedlings to carry on photosynthesis in weak light.

(6) The effects of variations in temperature and humidity incident to shading were so slight in this experiment that they could not be detected by a comparison of the plants in the bed in which these conditions were equalized by the use of an electric fan with the plants in the bed in which no attempt was made to equalize conditions by this means. Differences in shade produced such marked effects on plant growth that the effects due to shading were entirely predominant, and compared with these the resulting effects of change in humidity and temperature were practically negligible.

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THE "ROUGH-BARK" DISEASE ON APPLE BRANCHES AND LEAVES.

BREUER & KESSLER CO. PHILA

Issued April 12, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 280.

B. T. GALLOWAY, *Chief of Bureau.*

THE "ROUGH-BARK" DISEASE OF THE YELLOW NEWTOWN APPLE.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., December 14, 1912.

SIR: I have the honor to transmit herewith a paper entitled "The 'Rough-Bark' Disease of the Yellow Newtown Apple," by Mr. John W. Roberts, Assistant Pathologist of this Bureau, and recommend its publication as Bulletin No. 280 of the Bureau of Plant Industry. This paper has been submitted by Mr. M. B. Waite, Pathologist in Charge of the Office of Fruit-Disease Investigations, with a view to its publication.

This manuscript contains an account of an apple disease the cause of which has hitherto been unknown, together with a description of the fungus causing it and methods for its prevention.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE "ROUGH-BARK" DISEASE OF THE YELLOW NEWTOWN APPLE.

INTRODUCTION.

For some years plant pathologists have been familiar with a disease of the Yellow Newtown apple tree which makes its appearance as a cankered or roughened condition of the bark on both trunk and branches.

In the summer of 1909 the attention of the writer was called to this disease, which is known to growers as "rough bark." So prevalent is this condition of the tree in certain sections of Virginia that many orchardists consider it a characteristic of the variety and use it as a means of identification. From this fact it will be apparent that the disease is not only widely distributed through Yellow Newtown orchards, but that it is sufficiently developed on individual trees to present a most striking appearance.

One may find trees which show the disease not only on the young 1-year-old wood, but also on the trunk and on all branches save those of the current year's growth. In the case of old trees which have not been properly cared for, the roughness and the cankered condition of the trunk and branches are particularly striking.

DESCRIPTION AND BEHAVIOR OF THE DISEASE.

The first appearance of disease is to be found in the sinking of certain definite areas of the bark, which later enlarge, turn black, and finally crack or break open about their margins. An examination of such spots shows that the underlying layer is blackened and dead. It is the shriveling and subsequent warping of these dead tissues, coupled with the ragged margins at the points where they break off from the healthy bark, which bring about the typical "rough-bark" effect. Plate I and Plate II, figure 1, showing the disease in its different stages, seem to justify orchardists in naming it "rough bark." The disease may continue to develop, sometimes involving an entire branch, or it may apparently die out and the wound heal over. In most cases, however, the blackened areas slowly enlarge, sometimes killing small branches by completely girdling them or leaving roughened or cankered places on the trunk or larger branches.

In the case of trees growing in poor soil or impoverished from other causes the disease may be quite destructive, entirely killing large limbs and adding to the pale, sickly appearance of the already unhealthy foliage. In most cases, however, only an occasional branch is killed and the tree lives on with its branches showing many roughened areas, its vitality doubtless somewhat weakened but without serious injury as long as it is in good growing condition. The chief complete destruction seems to be to the smaller branches, as the larger limbs and the trunk, though usually injured locally and badly roughened, are seldom deeply girdled.

So far as is known to the writer, the Yellow Newtown is the only apple variety susceptible to the disease. At least, it is the only variety growing in Virginia which is very seriously affected.

CAUSE OF THE DISEASE.

ISOLATION OF THE FUNGUS.

Cultures were made from diseased areas by Mr. W. M. Scott in 1907, and a fungus was isolated. In 1909 the same fungus was isolated by the writer from diseased spots which had only begun to develop. At various times since then the fungus, a species of *Phomopsis*, has been isolated from diseased branches and leaves of the Yellow Newtown and from the leaves of the York, Winesap, and other varieties of apples growing in Virginia.

INOCULATION EXPERIMENTS.

In the spring of 1910 inoculation experiments were made, using 1-year-old and 2-year-old wood of the Yellow Newtown apple. Spores from pure cultures of the fungus growing on corn meal were inserted beneath the bark through tiny slits. Only sterile instruments were used, and care was taken not to make ragged wounds. In order to close up the slits at once the branches thus inoculated were immediately bound round with raffia, which was removed one week later. Within a month there appeared about most of the points of inoculation darkened areas, which became larger and more nearly black as the season progressed. These places at the end of the season resembled very closely the dark, sunken areas which are typical of the initial stages of the disease. In nearly every case the inner bark was black and dead and the diseased area was quite definitely marked off from the surrounding sound tissues. An examination of these branches, which was made in July the following season, showed in and about 18 of the 24 points of inoculation the sunken roughened or cankered areas which are typical of the "rough-bark" disease.

Plate II, figure 2, shows the disease as produced by artificial inoculations. All show the black, sunken areas which have begun to

crack and break off. The fungus had nearly girdled the specimen shown in the center of this figure. The control slits had healed over nicely and showed no roughening or adjoining dead areas.

The trees selected for these inoculations were healthy specimens near the center of a 4-year-old orchard that was in fairly good growing condition and which was some distance away from the nearest orchard in which the disease was prevalent.

Branches thus diseased through inoculation with spores of the fungus were brought into the laboratory, and from the margins of the spots or cankers the fungus was reisolated, usually in pure culture.

In like manner the trunks and branches of young trees growing in the greenhouse were inoculated. In two months well-developed sunken spots possessing all the characteristics of the disease appeared. The fungus was reisolated both by plating the spores from the few pycnidia which had formed and through cultures from the diseased tissues.

Attempts were made to bring about infection by simply spraying spores on branches and on green twigs and water sprouts of the current year's growth, but in no case did the fungus gain an entrance. An abrasion or wound seems necessary before infection can take place.

Numerous inoculations made in orchards during the fall of the year have been uniformly unsuccessful. It would seem, therefore, from these experiments and from the observations as to the size of spots due to natural infection that the earlier part of the season is the time during which the fungus gains entrance and begins its development.

Since this same species of *Phomopsis* had also been isolated from leaf spots along with *Sphaeropsis malorum* even as early in the season as April, it was thought desirable to test its parasitism on leaves.

When spores were sprayed on healthy leaves, either in the orchard or in the greenhouse, no spotting resulted under ordinary conditions; but when a seedling apple tree growing in the greenhouse was thus sprayed and covered with a bell jar within which the air was kept saturated with moisture, an occasional leaf showed a few minute spots, from which the fungus was reisolated. However, the conditions and not the fungus may easily have initiated the spots, after which the fungus might readily have entered. Apple leaves, when moistened and covered with a bell jar, are likely to be spotted, especially if exposed to strong sunlight. That the fungus will grow on such dead spots is shown by the fact that when, in either orchard or greenhouse, spores were sprayed on leaves which had previously been burned slightly with a hot needle, the fungus infested the dead areas and developed pycnidia on them within a week. The leaves

used in the orchard experiment were covered with a paper sack for 24 hours to prevent excessive drying out, while those used in the greenhouse were covered with a bell jar for the same length of time. The spots did not seem to enlarge much, if any, but became gray with reddish margins. As shown in Plate I and in Plate III, figure 1, such spots with numerous pycnidia are strongly suggestive of *Phyllosticta*, and indeed the fungus under such conditions might easily be mistaken for a *Phyllosticta* or a *Phoma*. When plates were poured and the fungus reisolated it fruited as a *Phomopsis*, having both *Phoma* spores and the long, slender, curved sort which Shear¹ calls *scolecospores*.

The fungus will also cause a rot of the apple. York Imperial apples, about one-third grown, very hard and green, were inoculated through needle pricks with spores from corn-meal cultures and then placed in moist chambers. In one month rotted spots from 0.5 to 1 centimeter in diameter were noted about most of the points of inoculation, and on the larger spots the pycnidia of a fungus were quite conspicuous. (See Pl. III, fig. 3.) A microscopic examination of pycnidia and spores showed them to be identical with those of the fungus concerned in the inoculations. The pycnidia contained both the *Phoma*-like and the long, slender, hooked spores, the latter being particularly abundant. Cultures from the margins of the rotted areas produced the fungus in pure culture, showing conclusively that it had been the cause of the decay.

Full-grown but solid, not fully ripe, specimens of Yellow Newtown apples were inoculated by inserting spores through breaks in the skin and then placed in moist chambers. In two weeks rotted areas 4 to 5 centimeters in diameter appeared about the points of inoculation, while the controls showed no decay. From the margins of these rotted spots also the fungus was reisolated in pure culture. Typical pycnidia and spores were also formed, as in the case of the green apples. It will thus be seen that the fungus, especially on ripe Yellow Newtowns, is able to produce considerable rotting, though such a rot apparently occurs seldom in nature.

DESCRIPTION OF THE FUNGUS.

On corn meal, corn-meal agar, and sterile apple wood the fungus fruits quite readily, but pycnidia formed naturally on apple branches are difficult to find, being rather obscure and apt to disappear rather quickly after spore discharge has taken place.

The globose pycnidia develop singly or sometimes in a raised stroma, which may be from 0.5 to 1 centimeter across. They are

¹ Shear, C. L. The ascogenous form of the fungus causing dead-arm of the grape. *Phytopathology*, v. 1, p. 116-119, 5 fig., 1911.

quite variable in size, those which develop in corn-meal cultures being rather large, while those on leaves are comparatively small. Average-sized pycnidia have a diameter of about 0.5 millimeter, but the range of size runs from 0.1 to 1 millimeter in diameter.

A cross section of a pycnidium (fig. 1) shows a dark outer layer of large-celled pseudoparenchyma; inside this is a thick, lighter colored layer of rather loose texture, making up the bulk of the pycnidial wall; next is a densely woven olivaceous or brownish layer, and within is a closely woven hyaline layer. The interior of the pycnidium is usually more or less plurilocular through the upward growth or invagination of the base or by an inward protrusion from the side.

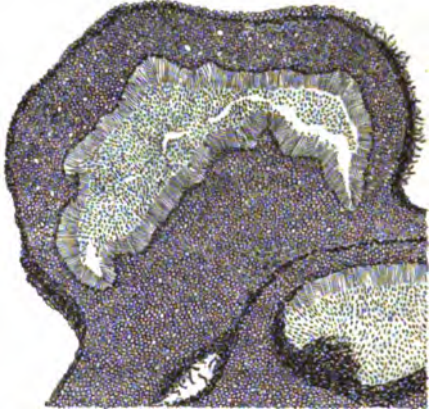


FIG. 1.—Section through a pycnidium of *Phomopsis mali* grown on corn meal.

The spore masses when mature are extruded either in an indefinite cream-colored or yellowish mass or in slender ropelike masses from 1 to 3 centimeters long. (Pl. III, fig. 2.)

The spores are of two kinds: Those called by Diedicke¹ α spores are spindle shaped or nearly so, measure 7 to 10 by 3 to 4 μ , mostly 8 by 3 μ , contain two oil drops, and are borne on cylindrical basidia measuring about 20 by 2.5 μ (fig. 2). They germinate readily in distilled water.

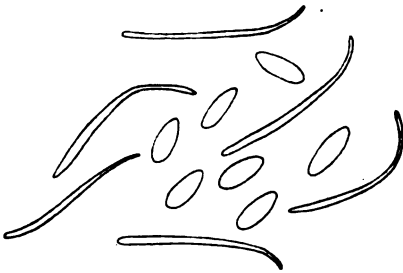


FIG. 2.—The two forms of spores of *Phomopsis mali* produced in one pycnidium.

Those which Diedicke designated as β spores and called by Shear scolecospores are threadlike, curved at the center, hooked at one end, sigmoid or nearly straight, somewhat attenuated and borne on short, conical basidia. They vary considerably in size, the average being 28 by 1.5 μ . Repeated attempts have been made to germinate these spores, but without success.

A pycnidium may produce spores all of one kind, but usually both kinds are found in the same pycnidium, though there is often a greater quantity of the one than of the other. Pycnidia developed on leaves show less tendency to form the long, curved sort than

¹ Diedicke, H. Die Gattung *Phomopsis*. *Annales Mycologici*, v. 2, p. 8-35, pl. 1-3, 1911.

those growing on either fruit or branches; in fact, this form of spore is rather difficult to find in pycnidia from leaves. For this reason the fungus as it appears on leaves may easily be mistaken for *Phoma mali* Schulz. and Sacc. On apple wood and fruit pycnidia produce both spore forms in abundance, some of them producing only one form, while others produce both. A localization of the production of the two kinds of spores in separate portions of the same pycnidium, as mentioned by Diedicke, has never been observed.

The fungus seems to differ essentially from other fungi described as occurring on the apple. *Phoma mali* Schulz. and Sacc., shown by Lewis¹ to cause a canker and soft rot of the apple, resembles it in the size of spores and growth on certain media, but differs from it in the absence of secondary spores, in the structure of the pycnidium, and in having less tendency toward stroma formation. The reactions of the two fungi toward certain culture media are also very different.

Fusicoccum viticolum, described by Reddick² and shown by him to cause a disease of the grape, resembles this fungus in the production of two similar spore forms, but differs from it in the size of spores and in that the pycnidia consistently develop in a stroma.

Phomopsis citri, described by Fawcett³ as the cause of a stem-end rot of citrus fruits, differs materially from this fungus both in pycnidial and spore characters, as does also the pycnidial form of *Diaporthe batatatis*, as set forth by Harter and Field,⁴ though both of these are evidently closely related to this fungus.

Accepting Saccardo's conception of the genus *Phomopsis* and Diedicke's investigations of the genus, the fungus in question is clearly a *Phomopsis*.

Of the described species of this genus the fungus resembles most closely *Phomopsis ambigua* (Nits.) Trav., described as occurring on the pear in Europe, but differs from it in having much larger secondary spores and is apparently different in other characters, though it is difficult to tell from the meager published description. Furthermore, *Phomopsis ambigua* is described as the imperfect form of *Diaporthe ambigua* Nits., associated with it on the pear, but no species of *Diaporthe* has ever been found in connection with this fungus.

¹ Lewis, C. E. Apple diseases caused by *Coryneum follicotum* and *Phoma mali*. Maine Agricultural Experiment Station, Bulletin 170, 1909.

² Reddick, Donald. Necrosis of the grapevine. New York (Cornell) Agricultural Experiment Station, Bulletin 263, 1909.

³ Fawcett, H. S. The cause of stem-end rot of citrus fruits (*Phomopsis citri* n. sp.). Phytopathology, v. 2, p. 110-113, pl. 8-9, 1912.

⁴ Harter, L. L., and Field, E. C. *Diaporthe*, the ascogenous form of sweet potato dry rot. Phytopathology, v. 2, p. 121-124, 4 figs., 1912.

It has therefore seemed best to the writer to describe it as a new species under the name of *Phomopsis mali*, as follows:¹

Phomopsis mali sp. nov.—Pycnidia subglobose, sparsis, gregariis vel in stromate, nigris, carbonaceis, plurilocellatis, ostiolatis. Sporulis subfusoidis biguttulatis, continuis, hyalinis, $7-10 \times 3-4 \mu$. Basidiis subulatis $20 \times 2.5 \mu$. Sporulis ordinis secundi filiformibus, uncinatis vel sigmoideis, attenuatis, $20-36 \times 1.5 \mu$.

Hab. in ramis truncisque et foliis Piri mali in Virginia, America boreali.

[Pycnidia subglobose; scattered aggregate or in a stroma, black, carbonaceous, plurilocular, ostiolate. Spores subfusoid, containing two oil drops, continuous, hyaline, measuring 7 to 10×3 to 4μ . Basidia awlshaped, measuring $20 \times 2.5 \mu$. Secondary spores threadlike, hooked, or S-shaped, attenuate, measuring 20 to $36 \times 1.5 \mu$.]

The vegetative portion of the fungus grows in the living part of the bark next to the wood, only its fruiting bodies appearing as minute blackish elevations, which break through the bark in diseased areas, giving them a pimplelike appearance. In these are contained the spores or reproductive bodies, which on being carried to wounds or small abrasions are under favorable conditions capable of germinating and producing the disease.

Many attempts have been made to find an ascogenous form of this species, but so far without success. As most of the known species of the genus have proved to be imperfect forms of Diaporthe, the writer has every reason to expect that eventually a Diaporthe will be found to be the ascogenous form of this fungus.

GROWTH ON CULTURE MEDIA.

On beef-agar slants.—White cottony, with numerous flocculi, which later turn black, becoming pycnidia, containing spores only in rare cases. On this medium the pycnidia do not occur in a stroma.

In corn-meal flasks.—Surface at first is covered with cobwebby mycelium, with numerous irregular raised places brownish in color. From these stromalike places spores are extruded in long, ropelike masses after one month's time. Pycnidia are also produced singly.

On corn-meal agar slants.—Mycelium forms a delicate film over surface of the medium. After 45 days long ropelike masses of spores are produced from pycnidia, which are usually separate but are sometimes in a stroma.

On potato cylinders.—Growth at first consisting of fine, flocculent, pure-white mycelium, which later becomes dark. Finally pycnidia are formed, which produce spores in slender, threadlike masses. Pycnidia are usually separate but may be in a stroma.

On prune-agar plates.—Mycelial growth cottony; pycnidia often formed in a stroma, as on corn meal. Spore masses appear after 20 days.

¹ Roberts, J. W. A new fungus on the apple. Phytopathology, v. 2., no. 6, p. 263-264, Dec., 1912.

On oxalic-acid agar slants.—After 12 days the surface is covered with powderylike growth, white with a tendency toward brown in some places. Neither pycnidia nor spores are formed on this medium.

On sterile apple wood.—Growth white and scant. Pycnidia and spores are formed abundantly in 30 days.

On synthetic agar slants.—After 15 days the medium is covered with a luxuriant growth of downlike mycelium, which later becomes dark at the surface of the slant.

On beef bouillon.—Delicate white hyphæ permeate the liquid in five days. Later the surface is covered with a crust of hyphæ having a white powdery surface. Pycnidiumlike bodies are produced on this crust next to the wall of the tube, but no spores are to be found.

PREVENTIVE MEASURES.

While definite spraying experiments for the control of this disease have never been carried on, observations in orchards which have been well sprayed both in growing and dormant seasons tend to show that such orchards may be as subject to the disease as those in which there has been little or no spraying, other conditions being the same. One of the orchards showing the disease the worst of any which the writer has seen had for several years past been sprayed in the winter with a strong solution of lime sulphur for scale, with dilute lime-sulphur solution once or twice in the early spring, and has besides received three or four applications of Bordeaux mixture during July and August. It is possible, of course, that spraying with bluestone or strong Bordeaux mixture before the buds open in the spring, with subsequent applications of weaker Bordeaux mixture during the early part of the growing season, might serve to check the disease, but it hardly seems probable. From the fact that fall inoculations have not been successful, spraying at that time of the year or in early winter for the control of this disease would seem of little value. When it is considered that the spores are protected by their pycnidial coverings under ordinary circumstances, oozing out only under moist conditions, and that the disease is probably initiated through the germination of spores which have lodged in small abrasions, hail marks, insect punctures, etc., the probability of successful spraying for its control becomes very remote. Spraying, therefore, probably is of value only in so far as in helping to maintain the general health of the tree it gives an increased resistance to disease.

From a commercial standpoint, careful pruning, proper cultivation, and, when necessary, fertilization seem quite successful as control measures, for as long as the trees are in good growing condition the disease will not be very serious.

SUMMARY.

The “rough-bark” disease of the Yellow Newtown apple in Virginia is caused by a new species of fungus, to which the writer has given the name *Phomopsis mali*.

As trees which are in good growing condition are usually exempt from attacks of the fungus, fertilization and cultivation, together with proper pruning, should act as preventives, and as checks where the disease has already gained a start. Spraying is apparently effective only in so far as it contributes to the general health of the tree.

The fungus will grow on leaves in spots previously diseased, often following *Sphaeropsis malorum* very closely in early spring, but is probably not a serious leaf disease.

A rot of the apple may be produced by this organism, but is probably of rare occurrence in nature.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) The "rough-bark" disease on apple branches and leaves.

Fig. 1.—A branch of a Yellow Newtown tree, showing the earlier stages of the disease.

Fig. 2.—A Yellow Newtown apple branch which shows the disease in its later stages. Fig. 3.—Apple leaves showing pycnidia of the fungus on areas which were first burned with a hot needle and then sprayed with spores.

PLATE II. Fig. 1.—Branches of Yellow Newtown apple trees, showing various stages of the "rough-bark" disease. Fig. 2.—Yellow Newtown apple twigs, showing the "rough-bark" disease produced by artificial inoculation with spores of *Phomopsis mali*. Both the incipient sunken stage and the later roughened stage are shown.

PLATE III. Fig. 1.—York Imperial apple leaves inoculated with *Phomopsis mali* through areas which had previously been burned with a hot needle. The fungus is fruiting on the spots. Fig. 2.—Growth of *Phomopsis mali* on corn meal, showing ropelike masses of spores after 60 days. Fig. 3.—York Imperial apple, about one-third grown, showing rot produced by artificial inoculation with the fungus, which is fruiting on the decayed spots. Note the ring of pycnidia on the largest spot.

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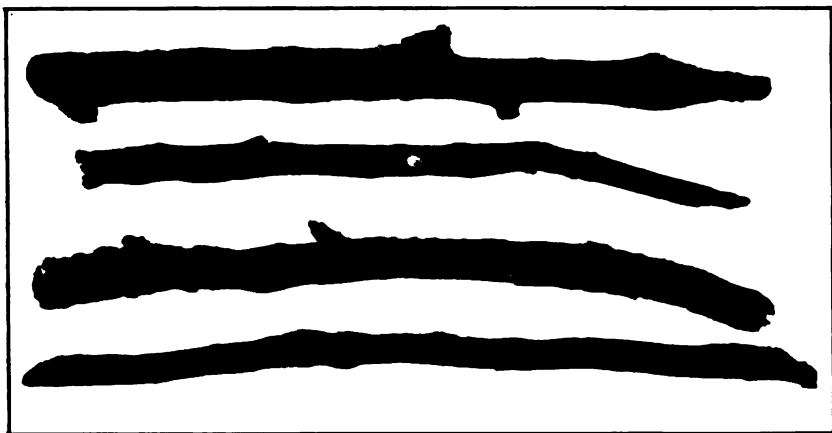


FIG. 1.—BRANCHES OF YELLOW NEWTOWN APPLE TREES, SHOWING VARIOUS STAGES OF THE "ROUGH-BARK" DISEASE.

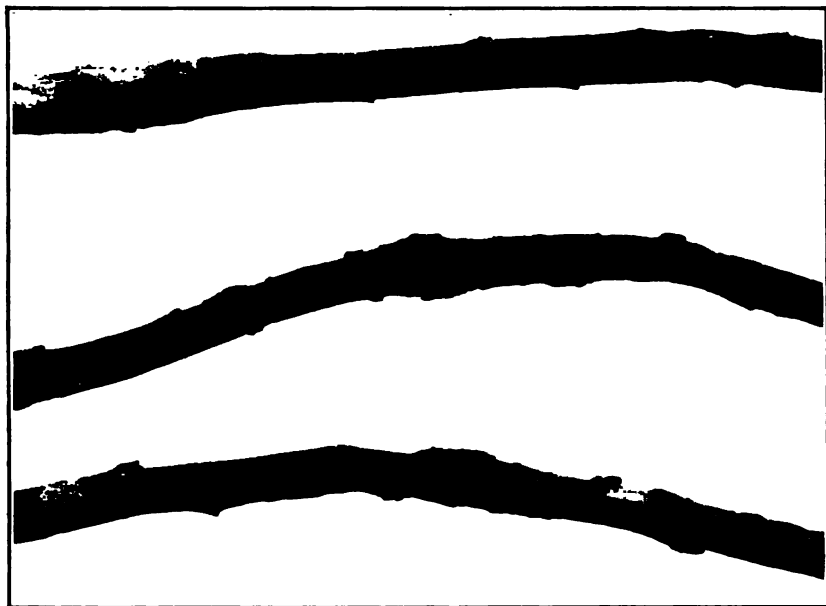


FIG. 2.—YELLOW NEWTOWN APPLE TWIGS, SHOWING THE "ROUGH-BARK" DISEASE PRODUCED BY ARTIFICIAL INOCULATION WITH SPORES OF *PHOMOPSIS MALI*.



FIG. 1.—YORK IMPERIAL APPLE LEAVES INOCULATED WITH PHOMOPSIS MALI THROUGH SCORCHED AREAS.



FIG. 2.—GROWTH OF PHOMOPSIS MALI ON CORN MEAL, SHOWING ROPELIKE MASSES OF SPORES.



FIG. 3.—YORK IMPERIAL APPLE, SHOWING ROT PRODUCED BY ARTIFICIAL INOCULATION.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., December 20, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as a bulletin of this Bureau a manuscript entitled "A Dry Rot of Sweet Potatoes Caused by *Diaporthe Batatatis*," by Mr. L. L. Harter, Pathologist, and Miss Ethel C. Field, Scientific Assistant, Office of Cotton and Truck Disease and Sugar-Plant Investigations.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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A DRY ROT OF SWEET POTATOES CAUSED BY DIAPORTHE BATATATIS.

INTRODUCTION.

In 1890 Halsted ¹ briefly called attention to a disease of the sweet potato (*Ipomoea batatas*) in New Jersey which he attributed to an undescribed species of *Phoma*. So far as we have been able to determine, this citation constitutes the first published reference to the disease. To this organism Ellis and Halsted assigned the name *Phoma batatae*.² Halsted stated in his discussion of the disease that the rot is only occasionally found, and for that reason he did not consider it of much importance. As a precautionary measure, however, he recommended that all decayed potatoes as well as the rubbish after each crop should be removed from the field and destroyed.

Halsted did not regard the disease as serious at that time, which probably explains why he did little or no more work with it. During the 22 years which have elapsed since this disease was first discovered and described, no additional work has been done with it.

It is believed by the writers, after a thorough study of this disease, that the economic importance of the dry-rot has been obscured by two very serious and prevalent diseases—the stem-rot and the black-rot. It has been further obscured by the fact that there are no external evidences of the organism in the field, it being detected only on the dead vines in the field or on the roots in the storage house a month or more after the crop is harvested. In view of these facts, injury which has been occasioned by the dry-rot organism is frequently attributed to other diseases, such as stem-rot or even to drying up due to natural causes.

Specimens of dry-rot have been received from a number of States. In 1910 and during the spring and summer of 1911 diseased plants were collected in New Jersey and Virginia. The disease was reported by Dr. R. P. Hibbard, then pathologist of the Mississippi Agricultural Experiment Station, to be present in Mississippi in 1908 and 1910. During the summer of 1911 Mr. N. N. McDonald, of Edna, Tex., sent in some diseased plants for examination. The organism

¹ Halsted, B. D. Some fungous diseases of the sweet potato. New Jersey Agricultural Experiment Station, Bulletin 76, 1890.

² Saccardo, P. A. Sylloge Fungorum, v. 10, p. 173, 1892.

was found on the lower part of the vines and on the roots, the fruiting bodies appearing after a period of 8 or 10 days' incubation in a moist chamber. The same year Dr. F. A. Wolf, pathologist of the Alabama Agricultural Experiment Station, reported the occurrence of dry-rot in two counties of Alabama. In February, 1912, four potatoes were sent in from Indiana by Mr. Ludwig, then a student at Purdue University, and two of them had well-developed cases of the disease. In November, 1912, the disease was also found on vines of sweet potatoes received from Mr. Wallace O'Neal, of Aydlett, N. C. From time to time during the last two years, sweet potatoes have been collected from the Washington wholesale market, and on several occasions the dry-rot has been found. In most cases it was impossible, however, to get authentic data as to their source.

DESCRIPTION OF THE DISEASE.

Halsted in his description of this disease mentions its occurrence only on the roots. While it occurs more abundantly on the roots, it is not restricted to that part of the plant, but has been repeatedly found on the dead vines in the field and on the vines, petioles, and leaves of inoculated plants in the greenhouse.

The diseased potato is very much shrunken and wrinkled (Pl. I, figs. 1 and 2), finally becoming mummified. On the surface appear small pimples a millimeter or so in diameter lying close together and eventually covering the entire surface. If the epidermis is scraped slightly, the tissue beneath presents a coal-black carbonaceous appearance. Sections cut through this tissue show the numerous buried pycnidia¹ of the fungus causing the rot. The fungus enters the potato from the stem end and progresses slowly downward, eventually breaking down and destroying the cell walls. The contents of the cells become brownish, and the whole potato finally becomes dry and powdery. Stems thickly covered with pycnidia have been collected in the field, and pycnidia have been found very abundant on the stems of plants inoculated in the greenhouse. The stems of affected plants first turn yellow; and then, as they gradually die, slightly raised pimples appear, which finally break through the epidermis, showing the black pycnidia a millimeter or less in diameter lying close together. It was frequently found in the greenhouse that where the vines had grown very long a portion of the stem might be covered with pycnidia, while beyond the node where the vine had taken root the stem would be green and apparently healthy. Sections through the yellowed vine showed the mycelium of the fungus to be growing throughout the tissue of the stem.

¹ The fruiting stage on the root has been found only on the mummied potato. Fawcett in Bulletin 107 of the Florida Agricultural Experiment Station, 1911, makes a similar observation on the stem-rot of citrus fruits caused by a species of *Phomopsis*. He states that only rarely are spores formed on the decaying fruits in the grove, but are produced after the fruits become mummified upon the ground.

Pycnidia may also be found on the dead leaves¹ and petioles. They appear as small black dots scattered irregularly over the upper surface of the leaf.

PREVALENCE OF THE DISEASE.

THE DISEASE IN THE HOTBED.

Sprouts from diseased sweet potatoes which had been planted in sand in the greenhouse seemed at first to be perfectly healthy. It was found later, however, that the plants were diseased. This fact was established by cutting off the vines 8 or 10 inches long just below the node. After the vine had died back to the next node pycnidia would form abundantly on the dead surface. On these vines the stems were gradually killed back to the base, a yellowing of the stem preceding the formation of pycnidia.

The disease has been found on various occasions on the stems of plants in the old hotbeds which have been abandoned for the season. The pycnidia of the fungus do not develop on the living stem, but they appear on the dead stems as soon as the plants are killed by the crowded conditions of the hotbed or by other causes. Typical specimens of the disease were found in old hotbeds at Onley and Cape Charles, Va., in May, 1911. In June and July of the same year similar conditions were met with at Vineland, N. J. This would seem to suggest, as previously suspected, that the organism passes from the diseased potato used for seed into the young plants developed therefrom.

THE DISEASE IN THE FIELD.

It is difficult, if not impossible, to detect the presence of the disease in the field because of the fact that the fungus works so slowly and pycnidia do not form until the plant is in a languid or dying condition. This fact was brought out forcibly by some field inoculations made on the Potomac Flats during the spring of 1911. At harvest time plants which had been inoculated in June showed no evidence of being infected. It was thought hardly worth while to bring them into the laboratory after the examination made in the field. They were brought in, however, placed in damp chambers, and examined one or two weeks later. Out of 50 inoculated plants which showed no external evidence of the disease, 43 were found to be infected. In the fall of 1911, one or two weeks after digging, the organism was found on the dead vines in the field at Vineland, N. J. Since dry-rot is not discernible in the field at harvest time it is probably carried unsuspectingly into the storage house in the fall.

¹ The fungus isolated from the root, stem, and leaves has been compared culturally and morphologically and found to be identical. (See page 25.)

THE DISEASE IN THE STORAGE HOUSE.

The first signs of the disease appear in the storage house one month to six weeks after digging. The potatoes then show the characteristic dried, shriveled appearance starting at the stem end and gradually extending through the tissue. Later they become hard and mummified.

In view of the fact that the organism has been found on dead vines in the hotbed and in the field, and frequently in the storage house, there is little doubt that a complete cycle is formed by the fungus. The disease is undoubtedly carried on the slips into the field; thence into the storage house and subsequently on the "seed" to the hotbed.

THE FUNGUS.

Two forms of fructification of the dry-rot organism have been found—the pycnidial stage and the ascogenous stage. The pycnidial stage has been found frequently on the roots, stems, and leaves, but the ascogenous stage only in culture.

PYCNIDIAL STAGE.

In December, 1910, specimens of sweet potatoes were collected from the Washington market, which upon examination were found to be affected with the same disease that Ellis and Halsted described as *Phoma batatae*. The potatoes were considerably wrinkled at one end and somewhat powdery and browned within. Sections through the pycnidia showed that the organism present was not a typical *Phoma*, differing (1) in having two types of spores present (pycnospores and stylospores), (2) in chambering of the pycnidia, and (3) in the presence of a stroma. Additional specimens have been received and collected from New Jersey, Virginia, and elsewhere, showing similar macroscopic and microscopic characters.

The pycnidia found on the roots are at first buried, later breaking forth by a single ostiole. Longitudinal and tangential sections through the pycnidia show these to be irregularly chambered through lateral and basal projections of the wall (Pl. III, fig. 6). The pycnidia vary greatly in size, the side walls frequently coalescing, thus forming long continuous chambers. The ostiole varies considerably in length, in some cases being as long as the pycnidium itself.

The walls of the pycnidium are sclerotial to carbonaceous, the inner hyaline, the outer brown. Sections cut through the roots of all specimens examined show that the pycnidia are embedded in a well-developed stroma.

On the stems (Pl. I, fig. 3), petioles, and upper surface of the leaves the pycnidia, appearing as small, black specks, are at first covered but break forth more quickly than those on the roots.

They are numerous, usually separate, occasionally confluent, more or less globose, 60 to 130 μ by 60 to 110 μ , and have a short ostiole. A stroma is not found on the stems, petioles, or leaves.

The pycnospores are oblong to fusoid, 6 to 8 μ by 3 to 5 μ , continuous, hyaline, usually two guttulate; sometimes, however, with three oil droplets. They are borne on long hyaline, simple, continuous, filiform basidia, which are either straight or slightly curved (Pl. III, fig. 7).

In the same pycnidium with the pycnospores there may or may not be found another type of spore, the so-called stylospores. They are filiform, hook-shaped bodies, sometimes curved or rarely straight (Pl. III, fig. 5) 16 to 30 μ in length and continuous. The basidia are much shorter than those of the pycnospores (in most cases about half as long) and awl shaped (Pl. III, figs. 3 and 4). Stylospores or pycnospores may be found alone or together in the same pycnidium (Pl. II, figs. 1 and 2). They are commonly found on the roots and stems of the host, but have never been observed on the leaves or petioles. Repeated attempts to germinate the stylospores have been unsuccessful.

There has been considerable difference of opinion as to the nature and function of the stylospore. Saccardo¹ regarded them as conidiophores, "*Basidia acicularia, demum hamata*," in his description of the genus. Von Höhnelt² made a new genus, *Myxolibertella*, to include those species having two kinds of spores, the oblong spores like those in the genus *Myxosporium*, and the filiform ones similar to those in the genus *Libertella*. He enrolled this new genus in the order Melanconiales but later placed it in the order Phomatales, genus *Phomopsis*. Bubák³ and Diedicke⁴ both considered these filiform bodies as spores. In an extensive treatise of the genus, Diedicke for convenience designates the Phomalike spore by the Greek letter alpha (α) and the long, filiform, hook-shaped spore by beta (β). Reddick⁵ regards these spores in the organism causing dead-arm of the grape as paraphyses, placing the organism in the genus *Fusicoccum*, while Shear⁶ regards these same bodies as spores and designates them as scolecospores. We have followed Nitschke's⁷ terminology, using "stylospore" to designate the hook-shaped spore.

¹ Saccardo, P. A. *Sylloge Fungorum*, v. 18, p. 264, 1906.

² Höhnelt, Franz von. *Mycologische Fragmente*. *Annales Mycologici*, Jahrg. 1, p. 526, 1903.

³ Bubák, Franz. *Vierter Beitrag zur Pilzflora von Tirol*. *Österreichische Botanische Zeitschrift*, Jahrg. 55, p. 78, 1906.

⁴ Diedicke, H. *Die Gattung Phomopsis*. *Annales Mycologici*, Jahrg. 9, p. 8-35, pl. 1-3, 1911.

⁵ Reddick, Donald. *Necrosis of the grape vine*. New York Cornell Agricultural Experiment Station, Bulletin 263, p. 331, 1909.

⁶ Shear, C. L. *The ascogenous form of the fungus causing dead-arm of the grape*. *Phytopathology*, v. 1, p. 116-119, 5 fig., 1911.

⁷ Nitschke, Theodor. *Pyrenomyces Germanici*, p. 240 [1860].

ASCOGENOUS STAGE.

The ascogenous stage has not been found on the host itself, although it has been obtained in culture. Specimens of sweet potatoes affected with dry-rot and vines covered with pycnidia were collected in the fall of 1911, and wintered outdoors on the ground in a wire cage in the hope of obtaining the perfect stage on the host. When these were examined the following spring no perithecia were found.

The organism was isolated in plates from sweet potatoes collected at the Washington market in December, 1910, and transfers made to beef agar and later to corn-meal flasks. These flasks were not examined until March 8, 1911, when two were found to contain mature asci. The other two contained only pycnospores and stylospores. It was at once suspected that this might be the ascogenous form of the dry-rot organism.

On May 22, 1911, transfers from one of the flasks containing asci were made to two other corn-meal flasks. When these flasks were examined on July 7 no asci were present, but pycnospores and stylospores were abundant. On October 17 both flasks were found to contain mature asci and ascospores. Poured beef-agar plates were made from one of the flasks containing asci. Two asci were located in the plates and ringed with india ink. They were kept under close observation for one or two days or until they had germinated and it was evident that the colonies could be transferred to beef-agar tubes without any foreign spores, mycelia, etc., accompanying them. Usually about two days were required to accomplish this, the plates being kept in an ice box during the night. Transfers were made from each tube on August 14 to two corn-meal flasks (four in all). In about five weeks asci were abundant in all of these flasks, but their formation was preceded by the production of pycnospores and stylospores.

On October 9 additional poured plates were made of asci from one flask of August 14. Eight asci were isolated and transferred to beef-agar tubes. Four corn-meal flasks were later inoculated from each tube (32 flasks in all). On October 21 eight flasks were examined, and all contained pycnospores and stylospores but no asci. When examined on November 2 asci were found in 22 flasks, and on November 6 they were present in all.

On October 31 poured plates were made from a flask of August 14 containing asci and 15 isolations made. Subsequently, transfers were made to as many mutton-agar tubes. On November 7 two corn-meal flasks and two rolled-oat flasks were inoculated from each tube (making in all 30 corn-meal and 30 rolled-oat flasks). On November 8 two tubes of sweet-potato cylinders were inoculated from each isolation (30 in all), and on the following day an equal

number of tubes of string beans were inoculated. On November 20 pycnosporos and stylospores were abundant in all corn-meal flasks, and asci were found in all of them on December 15. On January 2, 1912, asci were found in all rolled-oat flasks and on the following day sparingly in tubes of sweet-potato cylinders, but none on string beans.

On December 19, 1911, poured plates were made from one of the corn-meal flasks of October 9, and 11 asci isolated and transferred to beef-agar tubes on December 22. Four days later two corn-meal flasks were inoculated from each tube (22 in all). On January 5, 1912, pycnosporos and stylospores were found in all flasks examined. On February 1 all these flasks but three contained asci, and on February 6 asci were found in the three remaining flasks, which did not contain them on February 1.

On January 8 eight flasks each of wheat, oats, rye, and barley (32 in all) and nine tubes of sweet-potato stems were inoculated with the mycelia in the tubes from which the preceding set of experiments was made.¹ In a week to ten days following, pycnosporos and stylospores were abundant. Asci were first observed in a flask of rye on February 1. On February 6 all the flasks contained asci and three tubes of the sweet-potato stems.

In studying the ascogenous stage of the dry-rot organism 36 asci in all have been isolated. When transfers were made from these strains to the proper medium, such as corn meal, perithecia were developed again in about 5 to 6 weeks. It is also interesting to note that on corn-meal flasks, and on other culture media where asci are produced, the pycnidial stage is developed first in 6 to 10 days. Preceding the development of the perithecia the pycnosporos germinate and for the most part are not present when the asci are formed, but this is not an invariable rule.

Preceding the formation of asci, numerous club-shaped bodies (Pl. III, fig. 10) resembling the straight or slightly curved stylospores are formed. These are usually shorter than the typically hooked stylospore (Pl. III, fig. 5) and somewhat broader at one end or sometimes slightly swollen in the center, usually containing a number of oil droplets. In some instances these bodies assume the shape of immature asci, although they are never so large. Sections made through the stroma have never shown them to be present in the perithecia, but only in the pycnidial chambers. Diedicke describes the β spores (stylospores) in young pycnidia of *Phomopsis casuarinae* as needle or rod shaped, almost straight, rigid, sharply outlined, with a length of 13 to 16 μ . In old pycnidia these had

¹ While the cultures from which these transfers were made were 17 days old a careful examination showed that only mycelia were present in the tubes.

assumed their characteristic bending and were usually over $20\ \mu$ long. In our cultures we have never observed that these club-shaped bodies assumed the characteristic bending and longer length upon aging as mentioned by Diedicke. They have been found only in the ascogenous strain, but are regarded of the same nature as the hooked-shaped bodies, the difference in form being due to a difference in the two strains. The typically hooked-shaped stylospore is also present, but not as abundant as the club-shaped bodies.

Apparently two strains have been obtained, one which does not form perithecia in cultures (at least under ordinary conditions) and another which produces perithecia readily. Culturally and morphologically the pycnospores and stylospores of the two strains are the same when compared on various kinds of media.

The perithecia are formed in a Valsalike stroma (Pl. IV, fig. 2) which is ashy gray within, carbonaceous without, with many exerted, subcylindrical beaks from one-half to 3 mm. in length (Pl. IV, fig. 1). They are subglobose (Pl. IV, fig. 3) 120 to $370\ \mu$ in diameter, and the majority of the stromata contain from 9 to 25 perithecia. It is seen from a tangential section that the perithecia are formed in the same stroma with the pycnidia, frequently in a ring inside but separate from the pycnidial chambers. There is often a considerable variation from this type, as would naturally be expected in artificial cultures. Occasionally there is a tendency to form a double row of perithecia, some being more or less superimposed or irregularly arranged in the stroma. In no instance have asci been found in the pycnidia or pycnospores and stylospores in the perithecia.

The asci are clavate to cylindrical in shape, sessile, 8 spored, 23 to $38\ \mu$ by 7 to $12\ \mu$ (Pl. IV, fig. 4). The spores are subelliptical, obtuse at both ends, hyaline, one septate¹ slightly constricted at the center, 2 to 4 guttulate and 8 to $12\ \mu$ by 4 to $6\ \mu$. The spores are usually arranged in two rows but occasionally in a single row and then obliquely. No paraphyses are present. The ascospores germinate in 3 to 5 hours at room temperature in hanging drop cultures made in distilled water or beef bouillon, the germ tubes usually coming from the side of the spore (Pl. IV, fig. 5) and growing very rapidly thereafter.

That this form represents the perfect stage in the life history of the dry-rot of sweet potatoes is based on the following facts: (1) The ascospore stage and the pycnidial stage were both derived from the same original isolation; (2) when a single ascus is isolated and

¹ On account of the presence of large oil droplets some difficulty was at first experienced in determining whether the ascospores were one or two celled. The septum was readily demonstrated, however, by making a mount of the spores in a solution of salicylic acid. The oil droplets soon disappeared and the presence of the septum became evident.

transferred to a corn-meal flask, a pycnidial stage is developed in 6 to 10 days which compares in every respect with the original strain; (3) the large numbers of asci isolated, which in all cases gave the same type of asci preceded by the pycnidial stage; and (4) successful infection obtained through inoculation from ascospore strain.

SYNONYMY.

After a careful study of the organism, it is evident that the imperfect form can not be referred to the genus *Phoma*, as was done by Ellis and Halsted, but that it probably belongs to the form genus *Phomopsis*. This genus is made up largely of forms which were originally classed as species of *Phoma*. Several characters, depending upon the author, have been emphasized as important in justifying this separation. Thus, Bubák¹ mentions two types of spores which evidently correspond to the pycnospores and what is here regarded as stylospores. He accordingly changed a number of fungi that were enrolled as *Phoma* to *Phomopsis*, among them *Phoma asparagi* Sacc. to *Phomopsis asparagi*. He furthermore calls attention to the fact that the spindle-shaped spores (pycnospores) and the septoria-like spores (stylospores) may occur together in the same pycnidium or separately. Similar observations have been made by Diedicke² who bases his claim for referring certain species of *Phoma* to *Phomopsis* to the following characters: (1) Chambered or locular pycnidia; (2) sclerotial stroma; (3) all forms having two types of spores, pycnospores and stylospores.

If Saccardo's classification is followed and the absence of stroma on the stem and leaves disregarded, the organism should be classed as a *Dothiorella* or a *Fusicoccum*, since *Phomopsis* is without a stroma. Following Diedicke's revision of the genus it is believed that the pycnidial form of this organism should properly be classed as a *Phomopsis*.

A comparison of type material of *Phoma batatae*, loaned by the New York Botanical Garden, with this species show that the two are identical macroscopically. A microscopic examination shows the pycnidia to be similar (1) in possessing a stroma, (2) in the chambering of the pycnidia, (3) in character of pycnidial walls, and (4) in having pycnospores and conidiophores which are of the same size and form. No stylospores were found in the type material.

The ascogenous form obtained in culture is a *Diaporthe* which in many species investigated by others has *Phomopsis* as the imperfect stage. The organism has been described as a new species, *Diaporthe*

¹ Bubák, Franz. Zweiter Beitrag zur Pilzflora von Montenegro. Bulletin de l'Herbier Boissier, s. 2, t. 6, p. 408, 1906.

² Diedicke, H. Die Gattung *Phomopsis*. Annales Mycologici, Jahrg. 9, p. 8-35, pl. 1-3, 1911.

batatatis.¹ Spegazzini² reports a species of *Diaporthe* (*D. ipomoeae*) occurring on *Ipomoea* sp. This species differs from *D. batatatis* in the following characters:

TABLE I.—Comparison of *Diaporthe ipomoeae* with *Diaporthe batatatis*.

Characters.	<i>D. ipomoeae</i> .	<i>D. batatatis</i> .
Asci.....	50 to 55×5 μ.....	23 to 38×7 to 12 μ.
Spores.....	10 to 12×3 μ, uniseriate, oblique; not or only slightly constricted at septum; 1 to 2 oil droplets.	8 to 12×4 to 6 μ, biseriata occasionally uniseriate; distinctly constricted at septum; usually 4 oil droplets.

On account of these variations we do not consider the species identical.

PARASITISM OF THE ORGANISM.

INOCULATIONS IN THE GREENHOUSE.

Sweet potatoes do not thrive under greenhouse conditions as well as many other crops. The vines grew very luxuriantly, sending out long runners so that they overlapped, the checks and inoculated plants frequently running together, though the pots were some distance apart. As a result some of the checks were diseased. Potatoes were seldom formed, and when they were they were small.

The potatoes from which the sprouts were obtained for inoculation purposes were originally secured from the Washington market and selected as being free from disease so far as it was possible to judge from external appearances. They were then sterilized in formalin 1 to 200 for 20 minutes and rinsed in distilled water.

The original culture from which the inoculations were made was obtained in December, 1910, from some sweet potatoes collected at the Washington market.

On February 13, 1911, six inoculations were made on sweet-potato plants growing in 6-inch pots. An incision was made at the base of the stem with a sterile needle and mycelium from pure cultures inserted in the opening. Two plants were left as checks; on September 22 one plant was lifted. Pycnidia were numerous on the dying stems, but none were found on the roots. The roots were placed in a damp chamber and reexamined on October 19. The surface was then found to be covered with fruiting bodies containing both pycnospores and stylospores. Pure cultures of *Phomopsis* were secured by planting small bits of tissue from the interior of the potato in plates of beef agar. On October 19 the five remaining plants were lifted; pycnidia were numerous on the dying stems, but they were not found on the roots. The roots were placed in a damp

¹ Harter, L. L., and Field, E. C. *Diaporthe*, the ascogenous form of sweet-potato dry-rot. *Phytopathology*, v. 2, p. 121-124, 4 fig., 1912.

² Spegazzini, Carlo. *Fungi Argentini novi v. Critici*. *Anales del Museo Nacional de Buenos Aires*, t. 6 (s. 2, t. 3), p. 270, 1899.

chamber and examined on November 20. Four plants were found to have pycnidia with pycnospores and stylospores and one with pycnospores only. Both checks were infected. That the checks were also infected is to be explained by the fact that inoculated plants and checks were standing close together on the bench. It would thus be easy for the checks to become infected through actual contact with the diseased stems of the inoculated plants or by washing spores from one plant to another while watering.

On April 4, ten more inoculations were made on plants grown on a side bench of the greenhouse. These inoculations were made in the same way as those of February 13. The cultures used had been grown on beef agar at room temperature for five days and had not yet fruited. Two plants were left as checks. On December 4 the plants were lifted. The roots were poorly developed in each case. All of the inoculated plants and one check were infected.

On April 25, twenty more plants were inoculated. For this experiment cultures were grown in beef-bouillon tubes for seven days. There was an abundant mycelial growth in the bottom of the tubes, and in a few cases a pellicle had formed. One tube of these cultures was poured on the soil around each plant which had been transplanted to 9-inch pots. Four plants were left as checks. On September 22, three inoculated plants were lifted and all were found to be infected. On December 15 the remaining plants were lifted and 5 were found to be infected, making 8 infected plants out of 20 which were grown in the infected soil. None of the checks were infected.

Frequent reisolutions have been made from inoculated plants and pure cultures of *Phomopsis* obtained, which were identical with the original strain.

INOCULATIONS FROM REISOLUTIONS.

The organism was recovered on November 18, 1911, from infected plants inoculated in the greenhouse on April 4 by planting bits of the diseased tissue from stems on beef agar. On November 23 transfers were made from one of these colonies to sterilized string beans from which inoculations were made on December 4. The plants inoculated were obtained from potatoes which had been selected as being free from disease, disinfected in formalin (1 to 200) for 20 minutes and planted in sterilized sand. The slips were then transplanted in sterilized soil in 9-inch pots. Inoculations were made in ten plants by inserting mycelium and spores in a needle prick made at the base of the stem. Three plants were left for checks.

All the plants were lifted on May 7, 1912, and placed in moist chambers in the laboratory. On June 10 these were examined and pycnidia of *Phomopsis* found on all. Stylospores were found on nine plants. None of the checks were infected.

INOCULATIONS FROM ASCOSPORE STRAIN.

Asci from corn-meal flasks were isolated on October 31, 1911, in poured plates of beef agar and transfers made to mutton-agar tubes November 3. On November 9 fifteen young plants in 9-inch pots were inoculated by pricking the base of the stem and inserting mycelia (no pycnidia had been formed) with a sterile needle. Six plants were left for checks.

The slips were secured from potatoes selected as free from disease, sterilized with formalin (1 to 200) for 20 minutes and bedded in sterilized sand. They were then transplanted in pots, the soil of which had been steam sterilized.

On April 26, 1912, all the plants were lifted and placed in moist chambers. Subsequent examinations showed that none of the plants were infected.

On December 19, 1911, asci from corn-meal flasks were again isolated, and on December 22 transfers were made to beef-agar tubes. On December 26 seventeen more young plants were inoculated in the greenhouse in the same way and under similar conditions to the above series. Pycnospores were present in the culture. The plants were lifted on May 4, 1912, but it was found by later examinations that only one infection had taken place.

On August 2, 1912, fifty young plants on the Potomac Flats were inoculated at the base of the stem in the usual way from a 28-day-old culture of an ascospore strain on corn meal (pycnospores present). The plants were lifted on October 11 and placed in damp chambers. When examined on November 6 typical pycnidia of the conidial stage of the fungus had developed on nine of the plants. Isolations were made from three of these plants and the organism recovered.

On August 16 ten plants were inoculated on the Potomac Flats from a 14-day-old culture (pycnospores present) and fifteen plants from a 43-day-old culture (pycnospores and ascospores present) on corn-meal flasks. The plants were lifted on October 11 and placed in damp chambers. When examined on November 6 two plants inoculated with the 43-day-old culture were infected.

On August 26 ten more plants on the Potomac Flats were inoculated from a 14-day-old culture (pycnospores present) on corn-meal flasks. On October 11 they were lifted and placed in damp chambers. None of these plants became infected.

Fifty plants of the same age were pricked on August 2 at the base of the stem with a sterile needle and left as checks. These were also lifted on October 11 and placed in damp chambers, but none became infected.

Of the 85 plants inoculated on the Potomac Flats from cultures descended directly from asci, 11 developed typical cases of the dis-

ease. In each case there was no external evidence of disease when the plants were first lifted, as was found true in the inoculations from pycnospore strains. The disease did not become evident until after a period of incubation in the damp chambers.

INOCULATIONS IN THE FIELD.

The field inoculations were made from cultures descended from the original strain of this organism. Plants of the Commercial Jerseys were placed at our disposal on the Potomac Flats by Mr. W. R. Beattie, of the Office of Horticultural Investigations, and 25 were inoculated on June 12 and 25 more on June 19, 1911. Fifty checks in all were left at some distance from the inoculated plants. All the plants were inoculated at the base of the stem by making an incision with a sterile needle and inserting mycelium, spores, and a small bit of agar in the opening. The plants of June 12 were inoculated with a 6-day-old culture on beef agar and those of June 19 from a 9-day-old culture on beef agar.

The plants were lifted on October 20. The vines were cut off about 6 to 8 inches long and, with the smaller roots, were washed thoroughly in water and placed in moist chambers. In 10 days to two weeks pycnidia containing pycnospores and stylospores formed abundantly on the stems and vines and some on the roots. Of the 25 plants inoculated on June 12 twenty were infected. Of those inoculated on June 19 twenty-three were infected. None of the checks (50 in all) were diseased. The organism was reisolated from a number of these plants and when compared culturally was found to be identical with the original strain. The dry-rot organism evidently was not present in the field, since none of the 50 plants left as checks contracted the disease. In view of these successful inoculations it was possible to gain some knowledge of the character of this disease on the living plant under field conditions. So far as general external appearances were concerned these plants showed no symptoms of disease. They grew normally all summer and produced a crop equal to that of noninfected plants. This disease has never been observed elsewhere to cause any damage in the field. It is believed from these observations that it must be regarded principally as a storage trouble, but that infection of the plant takes place in the field or hotbed. The organism apparently grows very slowly, and pycnidia are never formed on the living growing parts of the plant.

REISOLATIONS FROM GREEN STEMS.

Although pycnidia have been found in abundance on the stems of plants inoculated in the greenhouse and on stems from abandoned seed beds, they have been observed only on those stems which were

beginning to turn brown. Planted plates were made from sections of green stems to determine if the fungus could enter the living tissue or gain an entrance only after the stem ceases to function as a living organism. In some cases the selected stems were partially dead and a few pycnidia were forming, the other end being normally green. Other stems were selected in which the vine between two nodes was dead and covered with pycnidia; beyond the nodes these stems were green and apparently healthy. All isolations were made from green stems. The stems were first washed in tap water, sterilized in HgCl_2 (1 to 1,000) for about 40 seconds, and then washed in sterile water. The epidermis was peeled off and sections cut and planted on beef-agar plates with the following results:

On October 27, 1911, plates were made from 6 stems, of which 4 gave pure cultures of *Phomopsis*.

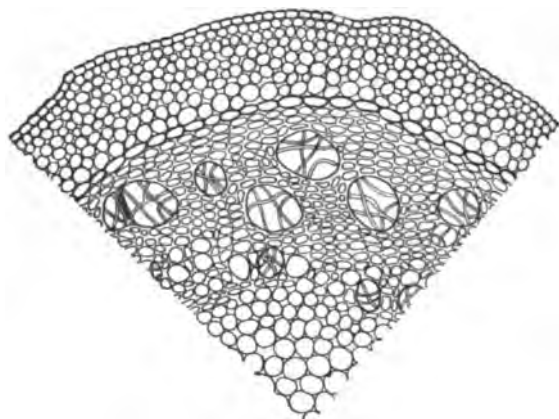


FIG. 1.—Section through a green sweet-potato stem, showing hyphae in the bundles.

On November 27 plates were made from 11 stems, of which 4 gave pure cultures of *Phomopsis*; 3, no growth; a *Fusarium* was obtained from 1, while the remaining 3 developed bacterial colonies.

On July 25 and December 4 additional plates were made from stems of

inoculated plants in the greenhouse and pure cultures of *Phomopsis* obtained. A record was not kept of the number of plants used. Isolations were again made March 1, 1912, from green stems and *Phomopsis* obtained (fig. 1).

SOME PHYSIOLOGICAL RELATIONS.

CULTURAL CHARACTERS.

Culture work was carried on quite extensively (1) in the hope of finding some medium which would produce the ascogenous stage and (2) to make a comparison of growth on some of the standard culture media.

INFLUENCE OF CULTURE MEDIA ON THE PRODUCTION OF ASCOSPORES.

The following media were used in an attempt to develop the ascogenous stage from the pycnospore strain: Sweet-potato cylin-

ders, sweet-potato agar, Irish-potato cylinders, corn meal, rice, string beans, beef agar, bouillon, sweet-potato stems, wheat, oats, rolled oats, barley, hulled barley, rye, buckwheat, mutton agar, and pork agar. A good growth was made on all of these media. Pycnospores formed on all the media and stylospores were produced in abundance on the following: sweet-potato cylinders, Irish-potato cylinders, corn meal, wheat, oats, rolled oats, barley, hulled barley, rye, and buckwheat. Pycnospores developed first in all the media, usually in about 5 days, the stylospores developing about two weeks later. Ascospores, however, were not produced.

An attempt was next made to see if acids or alkalis might prove effective in stimulating the fungus to produce ascospores. A definite amount of acid or alkali was added to sweet-potato agar, corn-meal flasks, and rice. A +10 medium of sweet-potato agar was first made up with the following acids: acetic, butyric, citric, formic, hydrochloric, malic, nitric, oxalic, phosphoric, and tartaric; a -10 NaOH was also used. Five tubes were inoculated for each test. Pycnospores and stylospores were produced in all the cultures, but no ascospores formed.

In making up the corn-meal flasks 10 grams of the meal were used, 60 c. c. of distilled water, and 1 c. c. of N/1 acid or the same amount of N/1 alkali were added to each flask. Besides the above-named acids and alkalis used in the experiments with sweet-potato agar, lactic acid, potassium hydrate, and sodium carbonate were added. Three flasks of each were used. A good growth was made in all the flasks except butyric acid, in which there was no growth, but no ascospores were formed.

The rice tubes were made up as follows: 0.75 gram of rice, 10 c. c. of distilled water, and 0.2 c. c. of N/1 acid or alkali added to each tube. The same acids and alkalis were used as those in the corn-meal flasks. Three tubes were inoculated for each test. No growth was made in the butyric-acid tubes. A good growth was made in all the other tubes, but no ascospores formed.

Thus far we have been unable to produce perithecia in culture from a pycnospore strain, although they are readily produced in corn meal, oats, barley, wheat, rye, and sweet-potato stems from an ascospore strain.

CHARACTER OF GROWTH IN DIFFERENT CULTURE MEDIA.

The behavior of an organism in certain culture media is sometimes so characteristic as to assist materially in its identification. Furthermore, other investigators may wish to repeat all or a part of the work recorded in this bulletin, and would in that case find such data of some value. For these reasons we have studied and recorded the growth of the dry-rot organism in nine of the more common culture media.

The media were not selected for any particular reason, except that they could readily be duplicated¹ by any one wishing to do so.

The inoculations were all made on the same afternoon (Feb. 14, 1912) from a 4-day-old culture (pyncospore strain) grown on beef agar. Five tubes (flasks in the case of corn meal) of each medium were inoculated and kept in the light in the laboratory, the temperature of which varied from 19° to 24° C. The cultures were examined frequently and careful notes made. The following records, given in number of days from the beginning of the experiment, briefly describe the character of the growth of the pycnidial stage of *Diaporthe batatas* on the different culture media.

SWEET-POTATO CYLINDERS (825).

This medium was prepared by the usual method from sound, healthy potatoes and steamed on three consecutive days. Sweet-potato cylinders have been one of the best of media for the growth of this organism.

One day.—A brown discoloration extending about half an inch from the point of inoculation formed on the potato slant; hyphæ sparse (difficult to see) growing close to the medium and extending almost over the browned area.

Two days.—Brown discoloration extended over practically the whole surface of the slant; mycelium scant, becoming whitish.

Three days.—Good growth becoming heavier and fluffier; white dotlike masses of mycelium, becoming dark, covering surface of slant.

Five days.—A few fruiting bodies formed containing only pyncospores.

Six days.—Heavy, white growth becoming brown in places. Fruiting bodies not abundant. Only pyncospores present.

Seven, nine, ten, and twelve days.—Only pyncospores present.

Thirteen days.—Fruiting bodies abundant, covering surface of slant; pyncospores exuding from pycnidia in small, yellowish brown globules.

Fourteen and fifteen days.—Only pyncospores formed.

Sixteen days.—Typical stylospores formed, but not abundantly.

Thirty days.—Stylospores very abundant.

In this experiment pyncospores were formed in 5 days and stylospores in 16 days on sweet-potato cylinders. Records were made of the time required for the production of pyncospores and stylospores in transfers made on September 11 and September 28, 1911. On cultures made on September 11 pyncospores were formed in 4 days and stylospores in 26 days; in those made on September 28 pyncospores were formed in 5 days and stylospores in 23 days.

SWEET-POTATO AGAR (804).

One day.—Very thin growth started.

Two days.—Thin growth growing close to surface of media; small, white dotlike masses of mycelium scattered over growth.

Three days.—Good, heavy growth; white dots (fruiting bodies) beginning to turn dark.

Five days.—Fruiting bodies abundant; mycelial growth white; pyncospores present.

Six days.—Fruiting bodies very abundant; only pyncospores present.

Seven, nine, ten, and twelve days.—No apparent change in cultures.

Thirteen days.—Pyncospores oozing out from pycnidia in a yellowish brown slimy mass.

¹ The record numbers of the media are given, by means of which it is possible to obtain a complete description of the method by which it was prepared.

Fourteen, sixteen, nineteen, twenty-one, and twenty-two days.—No change.

Twenty-three days.—Stylospores present.

Sweet-potato agar has been the best of the agars for the growth and development of the pycnidia of this organism, and for that reason has been utilized as one of the standard media throughout the whole investigation. While stylospores appear somewhat irregularly on practically all media they occur with as much frequency on sweet-potato agar as on any other medium with perhaps the exception of corn meal.

IRISH-POTATO CYLINDERS (822).

This medium was prepared in the usual way from sound, healthy tubers and steamed on three consecutive days. Irish-potato cylinders have been a good medium for the growth of the dry-rot organism.

One day.—Brown discoloration, about half an inch in diameter, starting at point of inoculation. Hyphæ very thin, extending almost over the browned area.

Two days.—Brown discoloration extended practically over entire surface of slant. Mycelium scant, turning whitish.

Three days.—Mycelial growth close to surface of slant and covered with white dot-like masses of mycelia, some of the white dots becoming dark in color.

Five days.—Fruiting bodies abundant, containing pycnospores.

Six days.—Fruiting bodies more abundant.

Seven, nine, ten, and twelve days.—Only pycnospores present.

Thirteen days.—Spores exuding from pycnidia as small yellowish brown globules.

Fourteen, fifteen, and sixteen days.—Only pycnospores present.

Nineteen days.—Stylospores found.

Pycnospores were produced in the above cultures in 5 days, while the stylospores were not formed for 19 days.

CORN MEAL (838).

Corn meal in flasks was prepared in the usual way and autoclaved. Corn meal has been found from every standpoint the best of any of the media used. The organism always grew well and formed pycnidia and both pycnospores and stylospores.

One day.—No growth visible.

Two days.—Very small white growth, starting at point of inoculation.

Three days.—Thin growth, with pycnidia forming on surface.

Five days.—Good mycelial growth; fruiting bodies and pycnospores present. The formation of fruiting bodies gives a dark color to the colony, which is surrounded by a border of white, fluffy mycelium.

Six, seven, nine, ten, and twelve days.—Only pycnospores present.

Thirteen days.—Only pycnospores present. Spores exuding from pycnidia in small, yellowish brown globules.

Fourteen, fifteen, sixteen, and nineteen days.—Only pycnospores present.

Twenty-one days.—Stylospores found.

Pycnospores were formed in 5 days and stylospores in 21 days. Cultures made on September 11 on corn meal formed pycnospores in 4 days and stylospores in 26 days.

RICE (834).

One day.—No growth visible.

Two days.—No growth visible.

Three days.—Thin, white mycelial growth; fruiting bodies beginning to form.

Five days.—Fruiting bodies abundant, containing only pycnospores.

Six days.—Only pycnospores present.

Twenty-eight days.—Stylospores present, but not abundant.

Forty days.—Stylospores abundant.

Pycnospores were formed in 5 days; stylospores in 28 days.

PRUNE AGAR (774).

Prune agar has never been an especially good medium for the growth of this fungus.

One day.—Small growth started.

Two days.—Thin, white mycelial growth on surface of media.

Three days.—Fruiting bodies beginning to form.

Five days.—Few pycnidia present containing pycnospores.

No stylospores were formed in 33 days.

BEAN AGAR (773).

One day.—Hyphæ just starting at point of inoculation.

Two days.—Thin, white mycelial growth on the surface of the medium.

Three days.—Mycelial growth becoming heavier and a few white dotlike masses of hyphæ scattered over the surface.

Five days.—Fruiting bodies and pycnospores present, but not abundant.

Six days.—Very heavy, white mycelial growth. Fruiting bodies not abundant.

No stylospores formed in 33 days.

BEEF AGAR (813).

Beef agar has not been a good medium for the production of pycnidia.

One day.—Growth just starting.

Two days.—Thin, white, finely branched mycelial growth on surface penetrating the agar.

Three days.—Thin growth; no fruiting bodies formed.

Five days.—No fruiting bodies formed.

Six days.—Good, white mycelial growth; fruiting bodies and pycnospores present, but not abundant.

No stylospores formed in 33 days. An examination made after 51 days showed stylospores had formed very sparingly in one tube.

BOUILLON (824).

Bouillon has not been a good medium for the production of pycnidia and has been used in only a few instances.

One day.—Growth just starting at bottom of tube.

Two and three days.—Cottony, white growth at bottom of tubes.

Six days.—White, fluffy growth growing up toward the surface of the bouillon.

Thirteen days.—Pellicle formed in one tube.

Sixteen days.—Pellicle formed on all tubes. Pycnospores present.

No stylospores formed in 33 days.

The dates on which pycnospores and stylospores were found are given in the following table. The circles (○) and the crosses (+) indicate the dates on which pycnospores and stylospores, respectively, were found. The cultures were made on February 14, 1912.

TABLE II.—*Dates on which cultures were examined and the first appearance of pycnospores (○) and stylospores (+).*

Media used.	Date of examination.																								
	February.												March.												Apr. 5.
	15	16	17	19	20	21	23	24	26	27	28	29	1	4	6	7	8	9	11	13	15	18	22	25	
Sweet-potato cylinders (825).....				○										+											
Sweet-potato agar (804).....				○															+						
Irish-potato cylinders (822).....				○										+											
Corn meal in flasks (838).....				○											+										
Rice (834).....				○																+					
Prune agar (774).....				○																					
Bean agar (773).....				○																					
Beef agar (813).....				○																					+
Bouillon (824).....													○												

It is seen from Table II that pycnospores form generally in about five days after inoculation and the stylospores somewhat later. The fruiting bodies appear at first as whitish, knotted masses (immature) on the substratum, but later turn black (mature). Pycnospores ooze out in a yellowish, viscous substance from the beak of the mature pycnidium. The fruiting bodies are much larger in culture and frequently provided with a long exerted beak.

It has been previously stated that the pycnidia occur on the root, stem, and leaves. No stylospores have been found in the pycnidia on the leaves, while they are commonly found in those on the stem and root. In view of this fact there was a possibility that they were different organisms. A comparison of the organism from root, stem, and leaf was made in cultures on different media. The results of this experiment are shown in Table III.

TABLE III.—Comparison of growth on different media of isolations from the root, stem, and leaves.

Media used. ¹	Date examined (in 1911).	Character of growth of organism from—		
		Root.	Stem.	Leaf.
String beans...	Oct. 3	No pycnidia ²	Pycnidia forming.....	Pycnidia forming.
	Oct. 7	Pycnidia (few).....	Pycnidia (many).....	Pycnidia (many).
	Oct. 21	Pycnospores present.....	Pycnospores present.....	Pycnospores present.
	Nov. 6 ³	do.....	do.....	Do.
Corn-meal flasks.	Oct. 3	Pycnidia in all flasks.....	Pycnidia in all flasks.....	Pycnidia in 3 out of 4 flasks.
	Oct. 7	Pycnidia numerous.....	Pycnidia numerous.....	Pycnidia numerous.
	Oct. 21	Pycnospores.....	Pycnospores.....	Pycnospores.
	Nov. 6	Pycnospores; stylospores.....	Pycnospores; stylospores.....	Pycnospores; stylospores.
Bouillon.....	Oct. 3	Growth cottony.....	Growth cottony.....	Growth cottony; pellicle forming.
	Oct. 7	do.....	do.....	Pellicle; a few pycnidia.
	Oct. 21	Pellicle (no pycnidia).....	No pellicle.....	A few pycnospores.
	Nov. 6	Pellicle, pycnospores.....	Pellicle; no pycnidia.....	Pellicle; pycnospores.
Sweet-potato cylinders.	Oct. 3	Pycnidia numerous.....	Pycnidia forming.....	Pycnidia numerous.
	Oct. 7	do.....	Pycnidia numerous.....	Do.
	Oct. 21	Pycnospores; stylospores.....	Pycnospores; stylospores.....	Pycnospores; stylospores.
	Nov. 6	do.....	do.....	Do.
Beef agar.....	Oct. 3	Immature pycnidia.....	Immature pycnidia.....	Immature pycnidia.
	Oct. 7	Pycnidia (many).....	Pycnidia (few).....	Pycnidia (few).
	Oct. 21	Pycnospores (few).....	Pycnospores (few).....	Pycnidia (no spores).
	Nov. 21	Pycnospores.....	Pycnospores.....	Pycnospores.

¹ The cultures were made on Sept. 28, 1911.

² For the sake of brevity, the word "pycnidia" has been used in the sense of fruiting bodies.

³ Examinations on various dates following Nov. 6 showed no change in the production of pycnospores or character of growth.

It seems evident from cultural characters that the organisms are identical. Numerous microscopical examinations and measurements of spores further justify this conclusion.

The mycelium has been carefully observed in different-aged cultures. On sweet-potato agar (841) the mycelia of 2-day-old cultures and cultures 3 weeks old differ somewhat in general character. In

either case it is very irregular in size, varying from $1.5\ \mu$ to $6\ \mu$ in diameter. From the first the cells are filled with granular bodies spherical or oblong in shape (fig. 2). While these bodies resemble

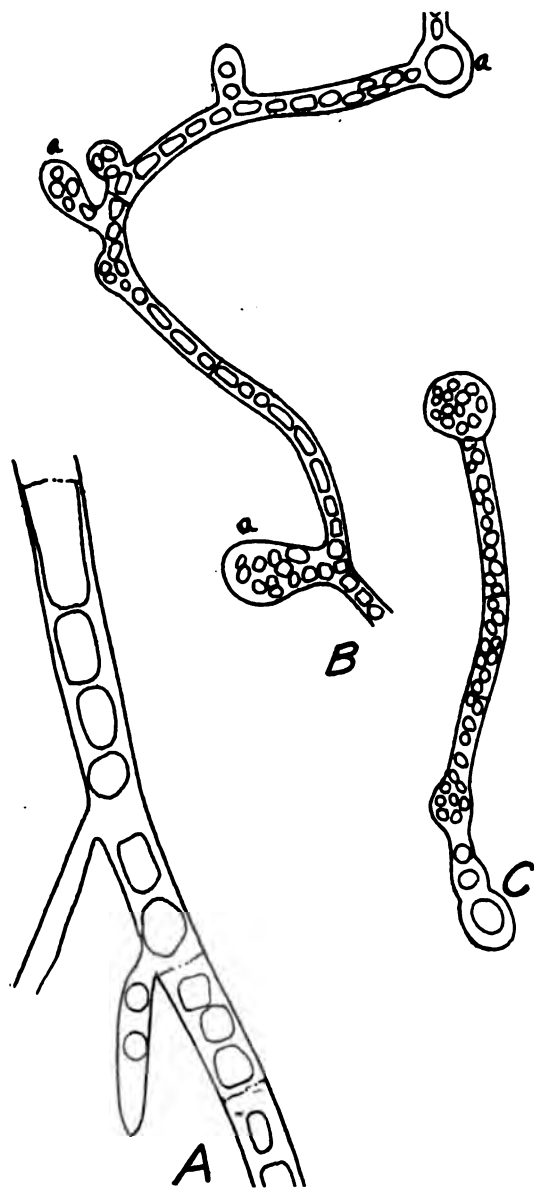


FIG. 2.—Hyphae from a 2-day-old culture grown on sweet-potato agar.

oil globules, they do not color red when treated with a solution of Sudan III. Mycelia of cultures 3 weeks old have the same general appearance, but respond readily to the test for oils or fats. The mycelia of these cultures have, in addition, irregular, spherical, or oblong bodies, formed intercellularly, or as budlike processes from the mycelium (fig. 2, B, a) provided with one to several large oil droplets. Three-day-old cultures in prune agar developed numerous irregular, masslike bodies (fig. 3), the origin and function of which are not known.

INFLUENCE OF TEMPERATURE ON GROWTH.

The temperature at which this organism can grow and likewise produce fruit is important in view of the conditions under which the sweet-potato crop is stored. Contrary to the custom for most stored crops, the temperature for sweet potatoes is maintained considerably above freezing. A temperature of 27° to 32° C. (80° to 90° F.) for 10 days to 2 weeks is generally recommended for curing; then reduced to 10° to 15° C.

(50° to 59° F.) during the remainder of the storage period. However, no careful experiments to determine this fact have been carried out so far as the writers are aware. Generally a higher temperature is maintained in most storage houses, bringing it within the range for the best development of most fungi. Thermographs were placed in storage houses in New Jersey for several months during the winter of 1911 and 1912 and the records show that the temperatures ranged from 16° to 22° C. (61° to 72° F.) and occasionally higher. It was seldom that the temperatures got as low as 10° or 12° C. in these houses.¹ It would be desirable if a temperature could be maintained which could meet all the requirements so far as the storage of the sweet potato is concerned and at the same time prohibit or retard the growth of the organisms which cause decay.

Cultures of the organism were made on sweet-potato agar (841) from a 5-day-old culture grown on sweet-potato agar, and three tubes were placed in each of 12 thermostats ranging in temperature from 0.5° to 38.6° C. and kept under observation for 18 days. One set of tubes was kept in the laboratory at room temperature as a check, it having been previously ascertained that this represented a good temperature for growth. The results of these experiments are recorded in Table IV.

Figure 4 shows that mycelial growth and the formation of fruiting bodies were greatly retarded at the lower temperatures. During the 18 days in which the experiment was conducted no growth occurred in Thermostats I and II (0.5 to 6.0° C.), or in XII (37 to 38.6° C.) after the first few days, during which a heavy aerial growth started at the point of inoculation. The mycelia attained its maximum growth in Thermostats X (23.8 to 27° C.) and XI (30.7 to 31.8° C.).

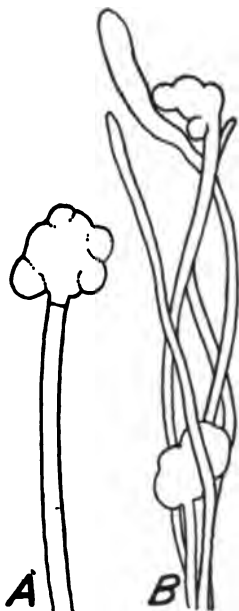


FIG. 3.—Hyphae from a 3-day-old culture grown on prune agar.

¹ In numerous instances where the relative humidity was determined by the sling psychrometer it was found to vary from 50 to 98 per cent. A relative humidity of 80 per cent was common. The relative high humidity, accompanied by a high temperature, provides optimum conditions for the dry-rot fungus.

TABLE IV.—Records of growth in laboratory room and 12 thermostats maintained at different temperatures ($^{\circ}$ C.)¹.

Date.	I. Ave., 1.09; Max., 1.8; Min., .5.	II. Ave., 4.2; Max., 6.0; Min., 3.3.	III. Ave., 7.5; Max., 9.2; Min., 6.0.	IV. Ave., 8.3; Max., 9.5; Min., 7.0.	V. Ave., 8.7; Max., 10.0; Min., 7.5.	VI. Ave., 12.3; Max., 14.0; Min., 11.2.	VII. Ave., 14.7; Max., 15.8; Min., 13.5.
Feb. 28..	No growth.	No growth.	No growth.	No growth.	No growth.	No growth..	Very thin growth of but few threads of hyphae; media slightly browned.
Feb. 29..	do.....	do.....	do.....	do.....	do.....	do.....	Very thin growth: only a few strands of hyphae arising from point of inoculation.
Mar. 1...	do.....	do.....	do.....	do.....	do.....	Very sparse growth.	Very thin growth, consisting of a few branched hyphae.
Mar. 2...	do.....	do.....	do.....	do.....	Very sparse growth starting on one tube.	Sparse growth.	Thin growth, 3 cm. in diameter.
Mar. 4...	do.....	do.....	do.....	Very sparse growth, a few millimeters in diameter.	Very sparse growth.	do.....	Fair growth, becoming white.
Mar. 5...	do.....	do.....	do.....	Sparse growth, 1 to 2 cm. in diameter.	Sparse growth.	Growth becoming whitish.	Good white growth; no pycnidia.
Mar. 6...	do.....	do.....	do.....	Thin growth.	Thin growth, 2 cm. in diameter.	Whitish growth not heavy, 3 to 4 cm. in diameter.	No pycnidia.
Mar. 7...	do.....	do.....	do.....	do.....	Thin growth.	Good white growth.	Heavy white growth; no pycnidia.
Mar. 8...	do.....	do.....	do.....	do.....	do.....	do.....	Do.
Mar. 9...	do.....	do.....	do.....	do.....	do.....	do.....	Do.
Mar. 11...	do.....	do.....	do.....	do.....	Growth becoming white.	do.....	Do.
Mar. 12...	do.....	do.....	do.....	Becoming white.	do.....	Heavy white growth; no pycnidia.	Do.
Mar. 13...	do.....	do.....	do.....	Good growth.	Good growth.	do.....	Do.
Mar. 14...	do.....	do.....	Thin growth starting on one tube.	do.....	do.....	do.....	Do.
Mar. 15...	do.....	do.....	do.....	do.....	do.....	do.....	Do.

¹ Temperature readings were made about 9.15 a. m. and 4.15 p. m.

TABLE IV.—Records of growth in laboratory room and 12 thermostats maintained at different temperatures (° C.)—Continued.

Date.	VIII. Ave., 16.2; Max., 17.0; Min., 14.5.	IX. Ave., 17.1; Max., 18.0; Min., 15.2.	Room. ¹ Ave., 22.5; Max., 26.0; Min., 20.0.	X. Ave., 24.9; Max., 27.0; Min., 23.8.	XI. Ave., 31.4; Max., 31.8; Min., 30.7.	XII. Ave., 37.8; Max., 38.6; Min., 37.0.
Feb. 28.	Very thin growth of but few threads of hyphae; media slightly colored.	Thin growth, 1 cm. in diameter; brown discoloration of media.	Thin growth, 2 to 2.5 cm. in diameter; brown discoloration of media.	Thin growth, 2 to 5 cm. in diameter; brown discoloration of media.	Thin growth, 3 cm. in diameter; slight discoloration of media.	Heavy aerial growth at point of inoculation, not spreading; slight discoloration.
Feb. 29.	Very thin growth.	Thin growth, 2 to 2.5 cm. in diameter.	Fair growth, not as good as in X or XI, 3 cm. in diameter.	Good white growth, 4 cm. in diameter; hyphae slightly raised from media.	Growth covering whole slant; hyphae slightly raised.	Growth not spreading.
Mar. 1.	Thin growth, extending 2 to 3 cm. in diameter.	Growth becoming whitish, 3 to 4 cm. in diameter.	Heavy growth.	Heavy growth; pycnidia starting to form.	Heavy growth; no pycnidia starting.	Do.
Mar. 2.	Growth becoming whitish, no pycnidia.	Growth becoming heavy; no pycnidia.	Heavy growth; pycnidia forming more abundantly than in X.	Heavy growth; pycnidia forming in all tubes.	Heavy growth, becoming somewhat brownish; no pycnidia.	No further growth.
Mar. 4.	Not as good as IX; no pycnidia.	No pycnidia.	Pycnidia very abundant.	Pycnidia not as abundant as in room, but larger.	No pycnidia.	Do.
Mar. 5.	Good growth; no pycnidia.	do.	do.	do.	do.	Do.
Mar. 6.	No pycnidia.	do.	do.	Pycnidia much larger but not as abundant as in room.	A few pycnidia beginning to form.	Do.
Mar. 7.	do.	do.	do.	do.	Pycnidia forming on all tubes.	Do.
Mar. 8.	Heavy white growth; no pycnidia.	do.	do.	do.	Pycnidia not abundant.	Do.
Mar. 9.	do.	do.	do.	Beaks becoming abundant on pycnidia.	do.	Do.
Mar. 11.	do.	One pycnidium formed on one tube.	do.	do.	do.	Do.
Mar. 12.	do.	Pycnidia forming in all tubes.	do.	do.	do.	Do.
Mar. 13.	do.	do.	do.	do.	do.	Do.
Mar. 14.	do.	do.	do.	do.	do.	Do.
Mar. 15.	Pycnidia forming in two tubes.	do.	do.	do.	do.	Do.

¹ The cultures were placed on a table in the laboratory with northern exposure.

² For the sake of brevity, the word "pycnidia" has been used in this table in the sense of fruiting bodies.

Fruiting bodies were formed in Thermostat VIII (14.5 to 17° C.) at the end of 18 days; in IX (15.2 to 18° C.) at the end of 14 days; in room (20 to 26° C.) at the end of 5 days; in X (23.8 to 27° C.) at the end of 5 days; in XI (30.7 to 31.8° C.) at the end of 9 days. The optimum temperature for the formation of fruiting bodies appears to be between 20 to 27° C. Fruiting bodies were much more abundant but smaller in the tubes in the room than in Thermostat X, light probably having more influence on development than temperature.

The organism was not killed in Thermostats I and II (0.5 to 6.0° C.) and XII (37.0 to 38.6° C.), but growth was inhibited. Tubes from Thermostats I and II were removed on March 15 and placed in room temperature; those in XII were removed the day following. On March 20 these cultures were examined and a heavy mycelial growth

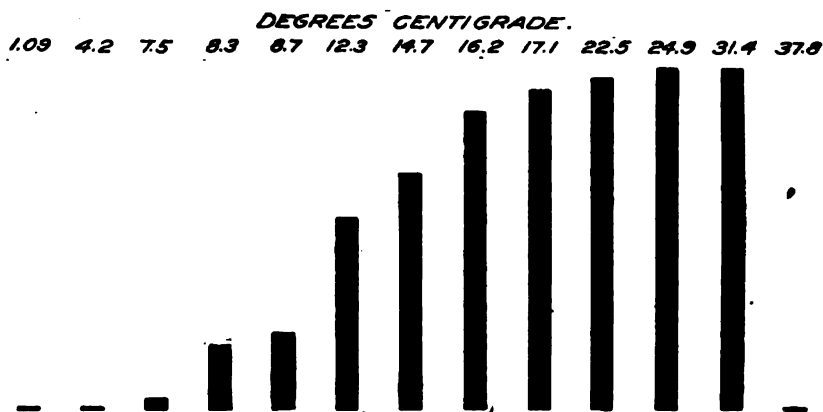


FIG. 4.—Graphic representation of growth on sweet-potato agar at different temperatures.

producing numerous fruiting bodies was found in all the tubes. Cultures removed from Thermostats IV and VI also fruited abundantly when brought into room temperature.

It should be remembered that these results are only approximate, no attempt having been made to establish absolute limits. There is considerable difference between 31.4° C., where growth is good, and 37.8° C., where none takes place. The exact temperature at which growth is prohibited can be established only by extensive experiments.

INFLUENCE OF LIGHT ON THE GROWTH AND FORMATION OF FRUITING BODIES.

Considerable difficulty was experienced at different stages of the work to induce the formation of fruiting bodies on beef agar. In some cases fruiting bodies would form abundantly, then again they were not produced. Usually the cultures were kept in a thermostat at an almost uniform temperature, but even then fruiting bodies

were in general only sparingly formed.¹ On the other hand, cultures on the same medium placed in parts of the laboratory exposed to light would develop numerous fruiting bodies in a comparatively short time. This naturally suggested the possibility that light was the important factor so far as the production of fruiting bodies was concerned. Tubes of slanted sweet-potato agar (841) were inoculated with the spores and mycelia of the organism on March 9, 1912. Four tubes were set on the laboratory table in the center of the room fully exposed to the light which was admitted from two large north windows. Four tubes were placed about a foot from one of the windows and directly exposed to the light, while four others were set in a tin crate and covered with two thicknesses of black cloth through which little or no light was admitted. The temperature at the middle of the laboratory varied from 18 to 24° C. and averaged about 22° C. Near the window the temperature was one or two degrees lower.

At the end of 48 hours little or no difference could be seen between the mycelial growth in the tubes exposed to light and those in the dark. In fact, the tubes in the dark gave as vigorous a growth of mycelia even to the end of the experiment as those exposed to light. There was, however, a very marked difference in the formation of fruiting bodies. Three days after the tubes were inoculated numerous white specks, which later proved to be inceptive fruiting bodies, appeared in the tubes exposed to light, while they were completely absent in those kept in darkness. One day later these bodies began to darken and pycnospores were found in them. On March 15 a few large scattered fruiting bodies were found in tubes in the dark and a few spores. On March 16 fruiting bodies were found abundantly over the whole slant of tubes exposed to the light. After March 18 no more fruiting bodies formed in any of the tubes. In darkness the fruiting bodies varied from 8 to 25 in each tube, while in those exposed to the light they were very numerous, perhaps several hundred in each. In the dark the fruiting bodies were 2 to 3 mm. in diameter, which is many times larger than those on the same medium in the light or on the host under natural conditions. The fruiting bodies formed in darkness, while apparently well developed, were frequently sterile, and at no time were spores exuded. On the other hand, in the light the spores were exuded in great abundance as large, viscous, yellow globules.

It has been repeatedly observed that cultures grown in the dark have much larger fruiting bodies but are fewer in number than those grown in the light.²

¹ Thermostats run at different temperatures gave similar results.

² Mycelial growth was found to be more vigorous in cultures grown in thermostats X and XI (Table IV), where the temperatures (23.8 to 31.8° C.) ran higher than in the room. The formation of fruiting bodies, especially in Thermostat XI, was much less abundant, however, than in the room. If these had been grown in the light instead of in the dark the fruiting bodies might have been much more abundant than in cultures grown at room temperature.

GERMINATION OF PYCNOSPORES.

Pycnospores germinate readily in hanging-drop water cultures at room temperature in about $3\frac{1}{2}$ hours. There is generally only one germ tube (Pl. III, figs. 8 and 9), occasionally two from each spore, and these may come from either the side or end.

INFLUENCE OF TEMPERATURE ON THE GERMINATION OF PYCNOSPORES.

The temperature at which the spores will germinate is of some importance for a crop which is handled like sweet potatoes. For several months they are kept in storage houses, and unlike the Irish potato, cabbage, and most other crops, must be stored at a rather warm temperature.

To determine the limiting temperatures for germination of the pycnospores, hanging-drop cultures were made in Van Tieghem cells in tap water from 6-day-old cultures grown on sweet-potato agar under sterile conditions. These were placed in Thermostats I, V, X, XI, and XII, and one set left in room temperature as a check. Examinations were made at the end of 17, 41, 65, and 113 hours.

TABLE V.—*Limiting temperature for the germination of pycnospores.*

Thermostat.	Temperatures.	Time in hours.			
		17	41	65	113
	° C.				
I.....	0.8 to 1.8	No germination.	No germination.	No germination.	No germination.
V.....	8.5 to 9.0	do.....	Slight germination.	.....	.....
Room.....	20.0 to 23.0	Some germination.	Good germination.	.....	.....
X.....	24.3 to 24.7	Good germination.	.....	.....	.....
XI.....	31.2 to 31.5	do.....	.....	.....	.....
XII.....	37.5 to 38.1	No germination.	No germination.	No germination.	No germination.

Table V shows that the optimum temperature for growth lies somewhere near or between 24.5° and 31.5° C. Careful observations showed no difference in the germination of the spores at these two temperatures. At room temperature, which varied from 20° to 23° C., germination was somewhat slower at the outset, but at the end of 41 hours was very good. At the end of 41 hours only a small percentage of the spores germinated at temperatures ranging from 8.5° to 9.0° C., and these made a feeble growth thereafter. The minimum temperature for growth lies somewhere between 9° and 1.8° C. At the latter temperature no germination took place at the

end of 113 hours. The maximum temperature for spore germination is somewhere between 31.5° and 38.1° C., but no germination took place at the end of 113 hours at temperatures varying from 37.5° to 38.1° C.

The hanging-drop cultures placed in Thermostats I and XII, after being removed therefrom, were kept at room temperatures for 48 hours. It is interesting to note that at the end of that time the spores from Thermostat XII did not germinate and evidently had been killed by the higher temperature. On the contrary, the spores from Thermostat I germinated at first somewhat feebly but rather vigorously later.

It is apparent that the pycnospores of the dry-rot fungus will germinate at the lower temperature generally recommended for the storage houses (about 10° C.). As the temperature rises above that point the spores germinate more readily, at least up to a temperature of 31.5° , but is completely prevented at 38° C. Either of these temperatures would be too high to store the sweet potato successfully.

VIABILITY OF PYCNOSPORES.

The viability of the pycnospores in cultures has been determined for only three media. The experiment was undertaken at the outset to determine the length of time the spores would live in cultures, it being presumed that their viability would be retained equally long on all media. String beans, sweet-potato cylinders, and beef agar were used for the experiment. Hanging-drop cultures were made in tap water in Van Tieghem cells. Tap water was used for the reason that it was previously found that spores would not germinate readily in distilled water.

Cultures were made on September 28, 1911, on string beans, sweet-potato cylinders, and beef agar, and hanging drops from these cultures on February 2, 1912. Four hanging-drop cultures were made from each medium on each of three consecutive days and no germination of spores from string beans and beef agar took place at the end of 24 hours. The spores from sweet-potato cylinders, on the other hand, germinated in a few hours at room temperature.

The whole series of tubes was examined on March 7, and it was found that the spores had completely disappeared. As a general rule the pycnospores do not endure in cultures very many months. Repeated search has failed to find them in old cultures. Whether or not they germinate and fail to produce pycnidia again is not certain. It is believed, however, that they disintegrate. On the stems the organism will live for six months and germinate readily at the end of that time. Pycnidia and spores were found on vines wintered

out of doors from October until the following June. At the end of that time pure cultures were secured, showing that the organism is probably carried through the winter by means of the pycnospores.

THERMAL DEATH POINT.

It has already been noted that cultures of this organism on sweet-potato agar, subjected to the average temperatures of 1.09°, 4.2°, and 37.8° C. for 18 days, made no growth. When these cultures were removed from the thermostat and placed in the room at a temperature varying from 18° to 24° C. a vigorous growth took place, which showed that the organism had not been killed during this period of incubation. Experiments were then made to ascertain how high a temperature would be required to kill pycnospores.

Beef-bouillon tubes¹ were inoculated with spores which were exuding from the pycnidia grown on sweet-potato agar. The cultures were immersed in a water bath at the desired temperature for 10 minutes,² the water being constantly stirred by a paddle operated automatically; the tubes were then removed and left in room temperature 1 to 2 weeks.

It was found that no growth occurred in any of the tubes exposed to a temperature of 49° C.³ or higher. Of the cultures 80 per cent grew when exposed to a temperature of 46° C.; 40 per cent at 47° and 48° C.⁴ While these results are only approximate, the thermal death point of the pycnospores evidently lies between 48° and 49° C. under these conditions.

TOXICITY OF COPPER SULPHATE TO PYCNOSPORES.

The toxicity of CuSO_4 was determined by means of hanging-drop cultures in Van Tieghem cells. In view of the fact that the spores did not germinate well in distilled water, the copper-sulphate solutions were made with tap water. The cultures were made from the spores that were oozing from pycnidia grown on sweet-potato agar. They were then placed in a thermostat run at a temperature of 25° C. Check cultures were made in tap water in which the spores germinated freely and made a good growth in 24 hours.

The results of the experiment showed that at the end of 48 hours the pycnospores would not germinate in a 1 to 100,000 CuSO_4 solution, but in a solution of 1 to 120,000 short germ tubes were pushed out in probably 5 per cent of the spores in 24 hours. When the

¹ Tubes of uniform size and thickness of glass were selected for all these tests.

² The temperature of the water during the period the tubes were exposed did not vary more than one-half of 1 degree.

³ Five inoculated tubes were exposed to a temperature of 49° C. on three different occasions.

⁴ Twenty inoculated tubes were exposed to a temperature of 47° and 48° C. on four different occasions.

solution was diluted 1 to 160,000 the percentage of germinating spores perceptibly increased and the germ tubes were much longer. Even at this concentration germination and growth were materially reduced. From these results it would seem that 1 to 120,000 is about the limit of toleration, since there was little or no increase in germination or growth at the end of one day more.

TABLE VI.—*Germination of pycnospores in tap water and in solutions of copper sulphate (CuSO_4).*

Date, March, 1912.	Length of time (hours).	Tap water.	Strength of solution.										
			1 to 5,000.	1 to 6,000.	1 to 10,000.	1 to 12,000.	1 to 20,000.	1 to 40,000.	1 to 80,000.	1 to 100,000.	1 to 120,000.	1 to 160,000.	1 to 200,000.
8	24	Germination.....	(1)	(1)		(1)							
9	24	do.....			(1)		(1)						
10	24	Good germination.....						(1)	(1)			(2)	
13	24	do.....											(2)
14	24	do.....										(2)	
15	24	do.....											
16	48	do.....							(1)				
18	24	do.....								(2)			
19	24	do.....										(3)	

¹ No germination.

² Small percentage just starting to germinate.

DISSEMINATION OF THE DISEASE.

The organism causing dry-rot of the sweet potato is undoubtedly distributed with the potato itself, and not to any extent by such agencies as the wind, insects, etc., as is the case with many other fungi. Probably the most conspicuous source of distribution is the potatoes selected for seed. A slight infection of the potato by this fungus is likely to be overlooked by anyone not familiar with the disease. Diseased potatoes when used for seed can be expected to give diseased slips, which in turn carry the organism to the field.

We have been able to prove in the greenhouse the transfer of the disease from the potato to the slip. Potatoes were selected which were known to have the disease and put in sand to sprout in one of the houses where no other sweet potatoes were growing, thus eliminating the possibility of infection from any other source. They sprouted freely and produced numerous plants which had the characteristic pycnidia on the vines and leaves. There is little possibility of detecting the disease on the slips in the seed bed before or even at planting time. The affected plants show no signs of the disease. The organism does not appear to be a destructive parasite, the host and parasite living in apparent harmony, at least for a considerable time. As soon, however, as the host is

weakened from any cause the parasite becomes evident by the formation of pycnidia and pycnospores. Hence, many diseased plants are likely to be carried undetected to the field, where the organism during the course of the summer may invade the roots. These roots are carried to the storage house, no one suspecting from their appearance that they are diseased. In the storage houses under favorable conditions, preferably warm and moist weather, the organism grows rather rapidly, invading and destroying all parts of the tissue of the potato, producing a dried, wrinkled condition. Potatoes infected in this manner are unsalable, and in the winter when they are picked over are discarded. These discards are disposed of in various ways, depending upon the available opportunities. Some people feed them to chickens, others to the pigs, and sometimes to cattle. They may or may not be cooked before feeding to stock. They generally are not. Those who do not feed them to stock throw them out on a pile and in the spring haul them onto the fields. Hundreds of bushels are disposed of in this manner. The dry-rot organism has been found in many instances in these piles.

METHODS OF CONTROL.

No experiments have been conducted in controlling this disease, but the methods to be employed would seem to be self-evident. Precaution should be the first consideration, and the following suggestions are made which if practiced it is believed will greatly reduce the loss from this disease. Great care should be exercised in the selection of potatoes for seed. When potatoes are selected for seed in the fall they should be examined again in the spring and those showing the slightest symptoms of the disease should be discarded. The seed bed should be made preferably of new soil, so that there is less possibility of the spores being present, or if old soil is used it should be sterilized, if possible, by steam at a temperature of 100° C. for one hour. In the absence of steam sterilization the beds may be soaked with formalin (40 per cent), one part to 200 parts of water. If the latter method is followed the soil should be treated 10 days to two weeks before it is to be used and stirred occasionally to facilitate the evaporation of the formalin. As an additional precaution, the potatoes before bedding should be disinfected with a solution of formalin (1 part of 40 per cent formalin to 200 parts water) or corrosive sublimate (1 part corrosive sublimate to 1,000 parts water) for 20 minutes, then rinsed in water and dried.

When it is desirable to feed the discarded potatoes to stock, they should be cooked. They should not be thrown on the manure pile to compost and then hauled to the field.

(1) The ascogenous form of the organism causing dry-rot of sweet potatoes is a *Diaporthe* and has been given the species name *batatatis* by the writers.

(2) The pycnidial stage was first described by Ellis and Halsted as *Phoma batatae*, but the imperfect stage has here been considered as belonging to the form genus *Phomopsis*.

(3) The disease is principally a storage trouble. It is characterized by a drying and shriveling of the potato, on the surface of which appear many small pimples, the pycnidia, lying close together and eventually covering the entire surface.

(4) The disease also occurs in the hotbed and in the field. The organism is not a vigorous parasite and consequently under ordinary conditions does not become evident until some time after harvesting. Diseased vines have been collected in abandoned hotbeds.

(5) The pycnidial stage develops from the ascospore in 6 to 10 days.

(6) Ascospores are formed from the ascogenous strain in 4 to 6 weeks on cereals, but they are always preceded by the formation of pycnidia.

(7) Both stages were derived from the same isolation.

(8) Inoculations with pure cultures of the pycnidial stage both in the greenhouse and in the field gave successful infections.

(9) Successful infections were also obtained from reisolutions.

(10) Inoculations on the Potomac Flats with pure cultures of the ascogenous strain gave successful infections.

(11) Isolations of the organism were secured in planted plates from green stems of infected plants. Pycnidia, however, form only on the dead or moribund tissue.

(12) In the greenhouse, pycnidia occur on the leaves, stems, and roots of inoculated plants.

(13) The ascogenous stage fruits well on all cereals tried and sparingly on sweet-potato cylinders and sweet-potato stems.

(14) Light and high temperatures stimulate the production of the fruiting bodies in culture.

(15) The disease is disseminated principally by means of the "seed" and by the use of decayed potatoes for manure.

(16) Diseased potatoes should be cooked before feeding to stock. They should never be scattered on the fields as a fertilizer.

(17) Seed beds should be sterilized and potatoes to be used for seed carefully selected.

DESCRIPTION OF PLATES.

- PLATE I. Fig. 1.—Sweet potato wrinkled by the dry-rot organism. Fig. 2.—Sweet potato, showing the darkened fruiting bodies of the dry-rot organism. Fig. 3.—Sweet-potato stem, slightly enlarged, showing the pycnidia of the dry-rot organism.
- PLATE II. Fig. 1.—Microphotograph of a longitudinal section of a culture on sweet-potato agar, showing pycnidia and stroma. Fig. 2.—A single pycnidium from figure 1 more highly magnified, showing the presence of pycnospores and stylospores.
- PLATE III. Pycnidial stage of *Diaporthe batatatis* Harter and Field. Fig. 1.—Longitudinal section through a pycnidium containing pycnospores. Fig. 2.—Tangential section from sweet potato, showing the arrangement of the pycnidia in the stroma. Figs. 3, 4, and 5.—Stylospores and conidiophores. Fig. 6.—Tangential section from sweet potato, showing the chambering of the pycnidium which contains stylospores. Fig. 7.—Pycnospores and conidiophores. Figs. 8 and 9.—Germination of pycnospores. Fig. 10.—Club-shaped stylospores found in connection with ascospore strain.
- PLATE IV. Ascogenous stage of *Diaporthe batatatis* Harter and Field. Fig. 1.—Longitudinal section through a fruiting body, showing elongated beaks. Fig. 2.—Tangential section through a stroma, showing a Valsalike arrangement of the perithecia. Fig. 3.—Tangential section through a perithecium, showing asci and ascospores. Fig. 4.—Asci and ascospores. Fig. 5.—Germinating ascospores.





FIG. 1.—SWEET POTATO WRINKLED BY THE DRY-ROT ORGANISM.



FIG. 2.—SWEET POTATO, SHOWING THE PYCNIDIA.

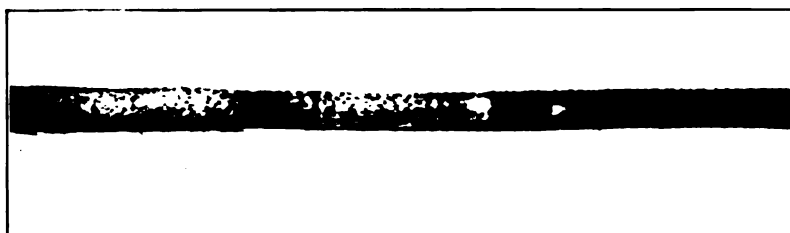


FIG. 3.—SWEET-POTATO STEM, SLIGHTLY ENLARGED, SHOWING THE PYCNIDIA.

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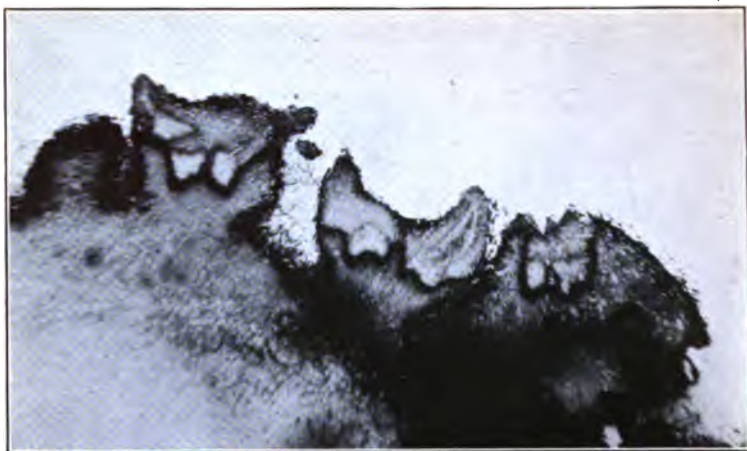
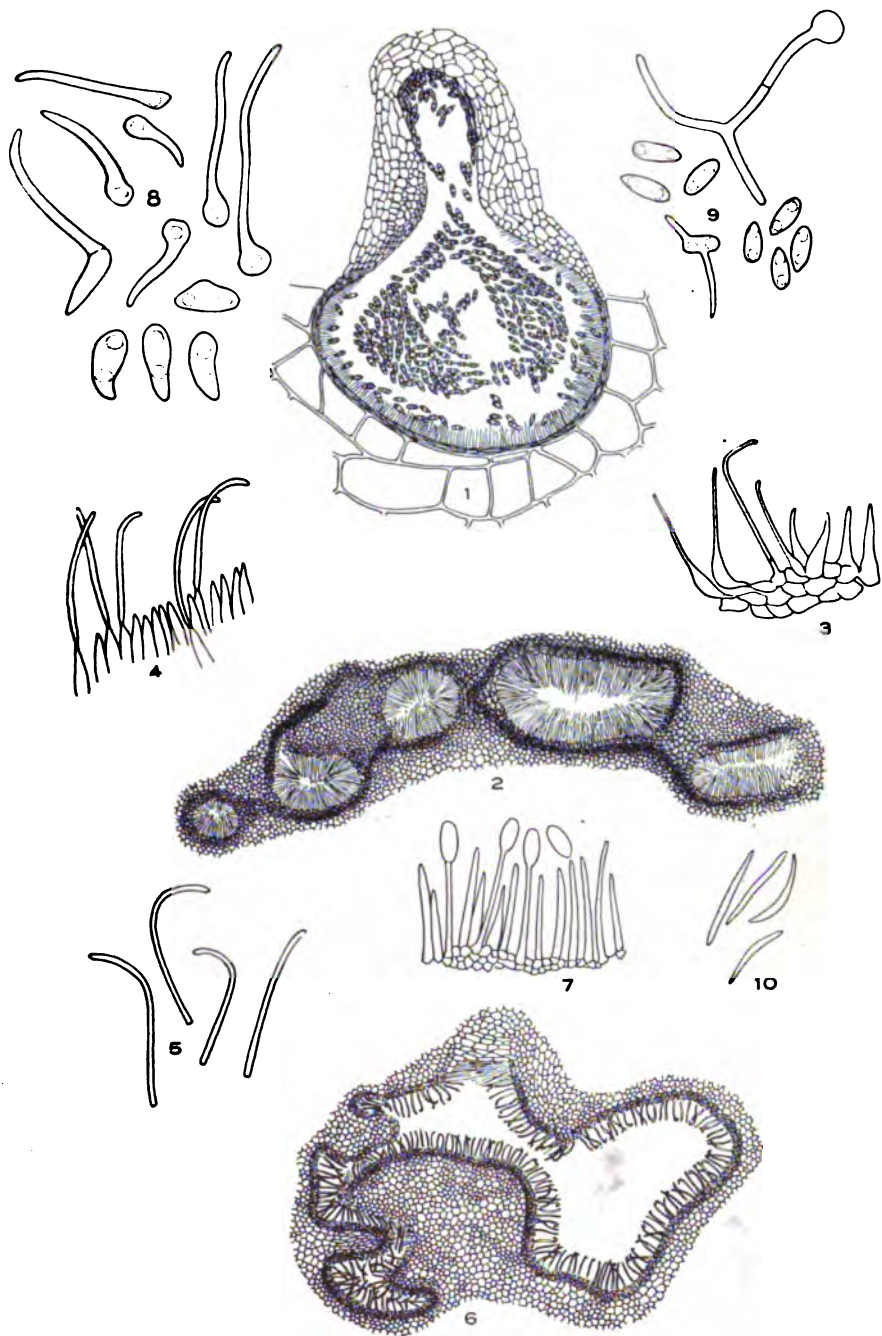


FIG. 1.—LONGITUDINAL SECTION THROUGH A GROUP OF PYCNIDIA GROWN ON SWEET-POTATO AGAR.

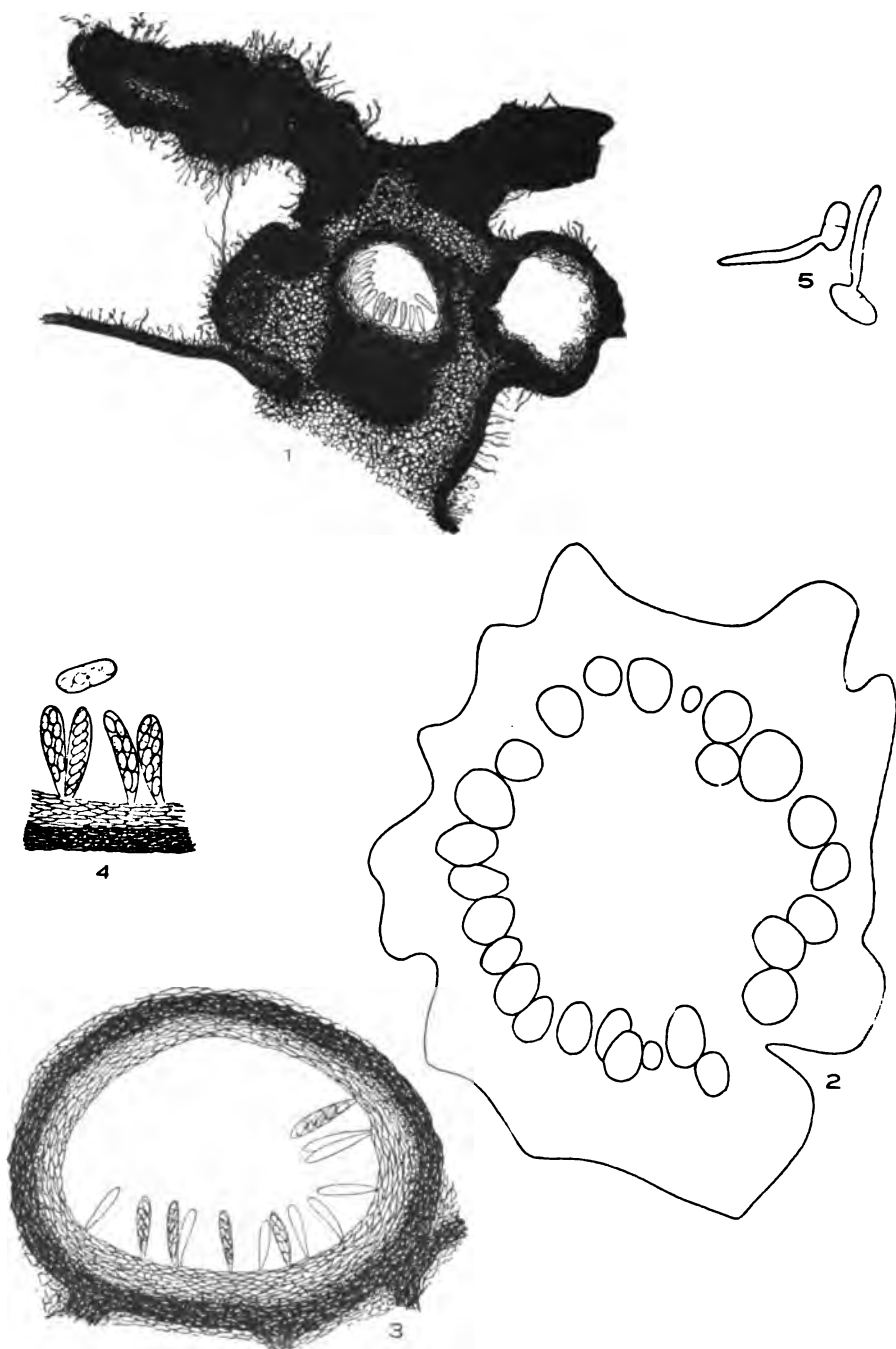


FIG. 2.—A SINGLE PYCNIDIUM FROM FIGURE 1 MORE HIGHLY MAGNIFIED.



PYCNIDIAL STAGE OF *DIAPORTHE BATATATIS*.

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ASCOGENOUS STAGE OF *DIAPORTHE BATATATIS*.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 281.

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A DRY ROT OF SWEET POTATOES CAUSED BY DIAPORTHE BATATATIS.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1913.



